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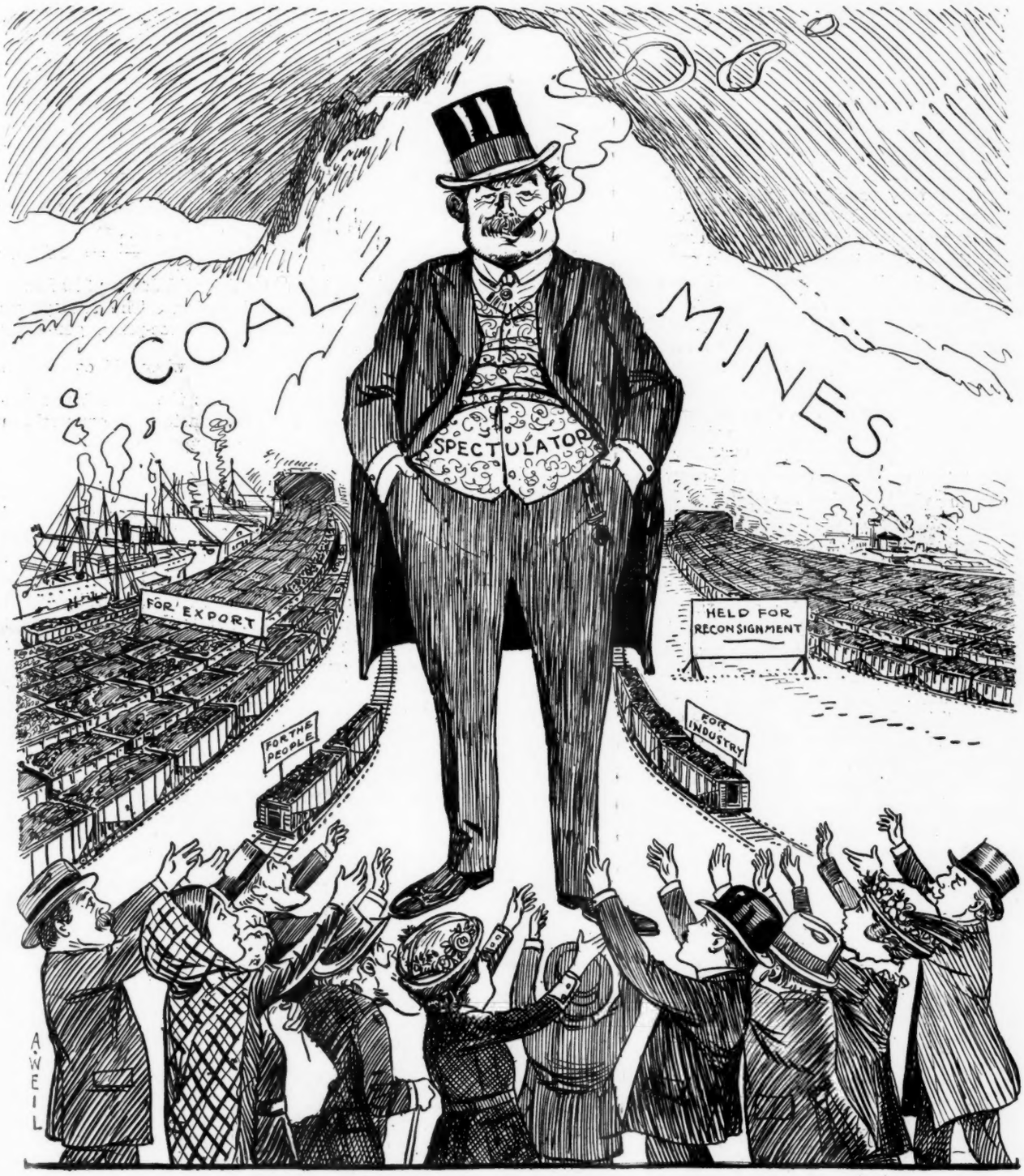

How Long Will This Condition Endure?

Connected Load Versus Generator Capacity

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Application of load in power plants having small power resources is a real problem—not a hit-and-miss proposition with troubles numerous and varied as an aftermath. There are limitations to field excitation, and the power factor of the load has a direct bearing, particularly during the starting periods of squirrel-cage induction motors.

SCATTERED throughout the country are many small isolated plants and central stations furnishing power to the local districts in their immediate vicinity. When these stations are located in a village or town, they usually supply street lighting and sometimes a connected power load for motor-driven ice machines and pumping units for town supply purposes. In addition to this there is a certain amount of industrial and private lighting load requiring electrical energy for the operation of this equipment.

In some of these plants the generating machinery consists of two prime movers so arranged that both units are run during the daytime when the maximum power-load condition prevails, and only one unit during the night to take care of the lighting and small power-load demand. In others of these stations only one prime mover is to be found, the daily 24-hour load factor being maintained as high as possible by operating the ice and pumping plants during the night, to balance up on the demand during the day.

There is always a temptation on the part of these small central stations, whether the equipment is driven by steam, gas engine or waterwheel, to accept contracts for delivering energy for operating a comparatively large number of induction motors which at times may be greatly underloaded or for operating induction motors relatively large as compared to the capacity of the generating equipment. Offhand it would appear to be a good thing to load up an otherwise underloaded equipment with a large number of motors or one or two big motors. However, the conditions are frequently not fully appreciated at the time these contracts are made. Everything runs along nicely until the new load is placed on the line, and the realization then comes that things are not as they should be. This condition of affairs applies not alone to the small central station, but to every other small plant such as might be found in any manufacturing concern generating electrical energy for its own immediate needs. It is a condition of affairs brought about through lack of a thorough understanding of some of the inherent characteristics of the prime mover, the electrical generating equipment, or the connected load in all of their essential points.

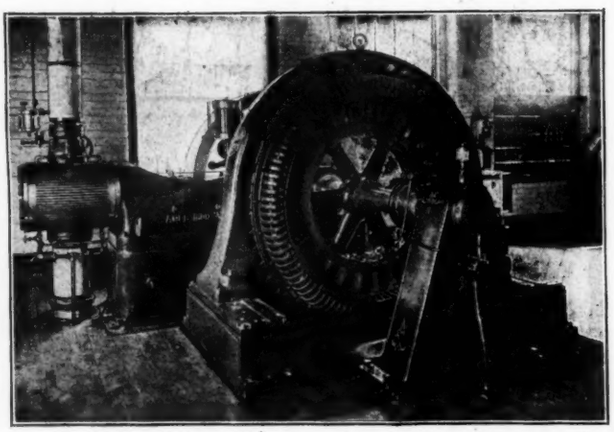


FIG. 1. STEAM-DRIVEN UNIT OF 100-KW. CAPACITY AT 80 PER CENT POWER FOCTOR

Consider a modern alternating-current system of generation such as is used in many small plants. A concrete example will show some of the inherent features of this type of equipment. Take, for example, a station having a single high-speed, direct-connected steam-driven unit similar to Fig. 1. The machine has a rating of 125 kva., maximum at 80 per cent power factor, 2,300 volts, 31.4 amperes, three-phase, 60 cycles, 257 r.p.m. Confining ourselves to the electrical end only of this equipment, the rating of the generator may be stated in a somewhat different manner. It might be said that the machine in question is capable of delivering 125 kva. (kilowatt-amperes) to a system requiring this amount of energy at 80 per cent power factor. In a three-phase alternator kva. $= \frac{EI \times 1.732}{1{,}000}$; in the machine under discussion, kva. $= \frac{2{,}300 \times 31.4 \times 1.732}{1{,}000} = 125$. Or it may be said that the machine will deliver 100 kw. of true energy at 80 per cent factor. The true power kw. (kilowatts) delivered by a three-phase generator is kw. $= \frac{EI \times P.F. \times 1.732}{1{,}000}$, where E equals the volts between terminals, I equals the current per terminal and $P.F.$ equals the power factor. In our problem kw. $= \frac{2{,}300 \times 31.4 \times 0.8 \times 1.732}{1{,}000} = 100$. Any alternating-current generator is capable of maintaining its voltage at normal speed and delivering an amount of wattless current (zero power factor) equal to the limit of its capacity, but represents zero energy or power. Under such conditions the engine would have to supply only the copper and iron losses in the generator, as it is delivering no true energy. It is therefore seen that in any alternating-current system the question of power factor cannot be overlooked.

Knowing the effect of power factor on the true power delivered, the limitations of an alternator can be best considered by referring to the curves in Fig. 2, showing the characteristics of the 125-kva. 80 per cent power factor 2,300 volt machine previously mentioned. If the terminals of the generator, when operated at its normal speed, are open-circuited and the fields excited with gradually increasing increments of direct current, then the terminal voltage for any given field excitation is shown by the no-load saturation curve *A*. If a 100 per cent power factor load of normal rating (31.4 ampere) is provided, more field excitation, 35 amperes, is required, as indicated by curve *B*, to maintain the terminal voltage of 2,300 than for no load. This is due to the impedence voltage drop in the armature and also the reactions of the load currents tending

to shift the field magnetizing flux, so that it is not as effective under load conditions as it is under no-load conditions. Curve *C* shows the further increased demagnetization effect of an inductive full-load current of 31.4 amperes at 80 per cent power factor. A field current of 48.5 amperes is required to maintain normal voltage. If an inductive full-load current of 31.4 amperes at zero power factor is provided (by means of special tests and test machines), still more field excitation, 57.5 amperes, is required to maintain the terminal voltage, as shown by curve *D*. Therefore it can be seen that in order to maintain the terminal voltage under full-load conditions and normal speed with gradually decreasing power factors, increased field excitation is required.

It is evident that there must be some limit to the maximum excitation that the fields of the generator can safely carry. Referring to Fig. 2, it is found that if the current in the field coils is maintained at any given value until the temperatures become constant, the temperature rise in the field coils, by resistance expressed in per cent, is shown by curve *E*. For full voltage of 120 on the exciter, the fields heat up 18.8 per cent (by resistance) and the maximum field excitation possible with hot fields is 52 amperes. It is, therefore, not possible to carry full-load current at zero power factor on the machine under consideration, because the limitations of the fields are such that the normal terminal voltage of 2,300 cannot be maintained. The machine is designed to carry its full-load current of 31.4 amperes at 80 per cent power factor and requires 48.5 amperes excitation. The fields have a slight margin up to 52 amperes, which can be used in cases of emergency such as short periods of overloads, temporary loads at power factors less than 80 per cent, etc.

On the 125-kva. generator under discussion, when carrying its full load at 80 per cent power factor, the

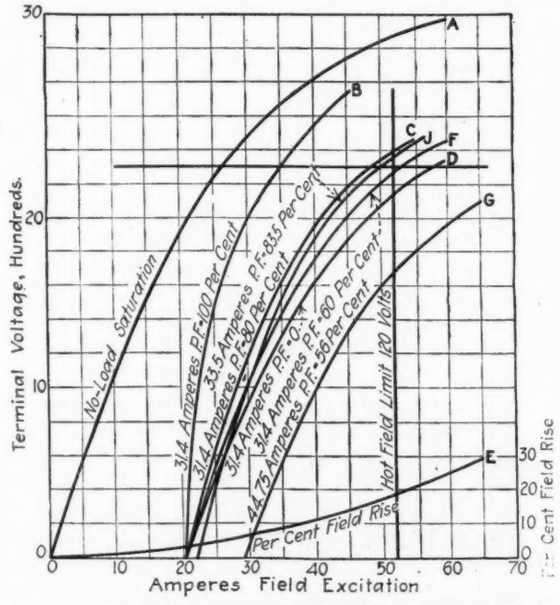


FIG. 2. CHARACTERISTIC CURVES OF THE 125-KVA. GENERATOR

fields heat up 16 per cent (by resistance) or, in terms of temperature, rise above an ambient air temperature of 40 deg. C. (104 deg. F.), the temperature rise in degrees Centigrade equals $16 \div (100 \times 0.00364) = 44$, where 0.00364 is the temperature coefficient of copper at 40 deg. C. (104 deg. F.).

To obtain the hot-spot correction according to the accepted rules of the American Institute of Electrical Engineers, a correction of 10 deg. C. (18 deg. F.) must be added to the value given, making a total temperature rise of 44 + 10 = 54 deg. C. (129 deg. F.). This is not unreasonable and is within the generally accepted safe working temperature for this class of machine. Furthermore, the field margin is small, and even under maximum field conditions such as might be used tem-

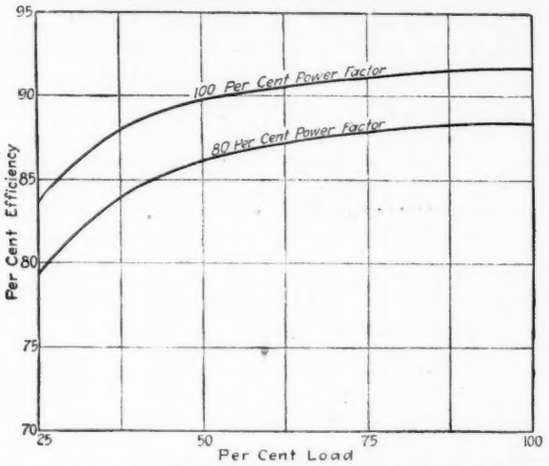


FIG. 3. EFFICIENCY CURVES, SHOWING EFFECT OF POWER FACTOR

porarily, the greatest temperature rise possible is 18.8 per cent = 51.5 + 10 = 61.5 deg. C. (142.4 deg. F.).

It then follows that a knowledge not only of the amount of actual load, but also of the power factor, must be given careful consideration. In addition to this the speed regulation of the steam engine, gas engine or waterwheel driving the generator cannot be overlooked. The curves of Fig. 2 are based on the exact normal speed of 257 r.p.m. being maintained. Any falling off in the speed immediately reflects in a falling off in the terminal voltage unless the field excitation can be increased to make up the discrepancy.

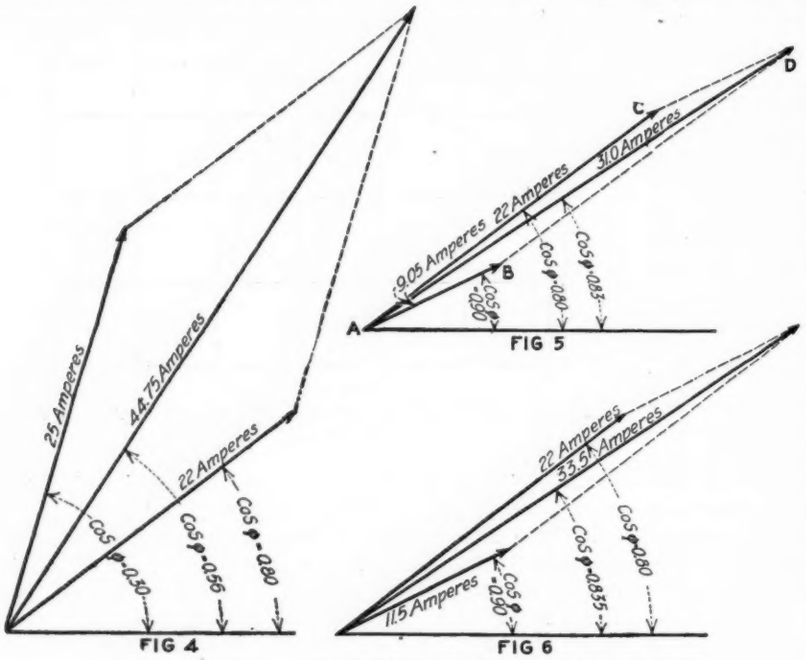
The small power plant is liable to load up, or to slightly overload a generator with a number of induction motors having a fairly low power factor. If the motors are underloaded, as is often the case, the condition may be further aggravated by still lower power factors, so much so that the alternator is unable to hold up its terminal voltage, as shown by curve *F*, Fig. 2. Sometimes the exciter is speeded up to give a higher voltage and thus afford the greater excitation necessary to hold up the voltage. The point is often overlooked that by so doing, the heating in the fields may be increased to a dangerous extent.

Another direct effect of low power factor is a decided falling off in efficiency. This is natural because the increased field current necessary to sustain the terminal voltage incurs an added loss in the field copper itself. Inasmuch as the power output remains constant and the losses increase, the efficiency drops off. This is shown by Fig. 3, which gives the actual efficiency curves for the 125-kva. alternator whose characteristics are shown in Fig. 2.

Consideration has been given to the effect of inductive loads as might be obtained by using a number of induction motors which at times may be greatly underloaded. There is, however, another important point relative to the use of this type of motor, which offhand might not seem of any great consequence. It is a question that requires a knowledge of the starting phenomena of

induction motors and can best be understood by a direct example.

Suppose that the 125-kva. alternator is carrying a load of only 70 kw. at 80 per cent power factor, or 87.5 kva. It might appear advisable to take on an additional load of a 40-hp. 2,300-volt induction motor of the squirrel-cage type. Combining this with the original load would give a total combined load on the generator of just about full load, or if the full-load efficiency of the induction motor is 92 per cent, the combined load would



FIGS. 4, 5 AND 6. COMBINING LOADS VECTORIALLY TO OBTAIN RESULTANT LOAD

equal $70 + (40 \times 0.746 \div 0.92) = 102.5$ kw. of true power.

If the full-load power factor of the induction motor is 90 per cent, then its full-load current equals $\frac{40 \times 0.746}{2{,}300 \times 1.732 \times 0.92 \times 0.90} = 9.05$ amperes, and may be represented to scale in magnitude and time phase relationship by the line *AB*, Fig. 5. Similarly, the line *AC* represents in like manner the 70 kw. at 80 per cent power factor equals $\frac{70 \times 1{,}000}{2{,}300 \times 1.732 \times 0.80} =$ the 22-ampere load. Combining these two vectorially, the resultant load is shown by the line *AD* and is 31 amperes or $\frac{2{,}300 \times 31 \times 1.732}{1{,}000} = 123.5$ kva., and the new power factor equals $\frac{102.5}{123.5} = 0.83$.

It will be noticed that the addition of the 40-hp. induction motor has raised the power factor of the whole system 3 per cent; that is, from 80 to 83 per cent. Apparently this is a good thing, but a study of the starting conditions of the squirrel-cage motor are necessary to determine all the effects the motor load has as regards the regulation of the alternator.

The usual method of starting a squirrel-cage induction motor is by means of a potential starter which impresses on the terminals of the stator winding a voltage less than normal in order to minimize the line disturbance that would be created by throwing the motor directly across the line. Incidentally, it is less of a shock to the motor and to the driven machine. After the motor is up to speed, the stator winding is connected directly across the line, as in diagram *B*, Fig. 7.

Assume that the 40-hp. motor in question, if thrown directly across the line, will draw a current of 59 amperes, or 6.5 times normal. While this is an unusual amount of current, it is characteristic of this type of machine. Another inherent feature is that the power factor is extremely low during the starting period, and in this particular case is 30 per cent, a fair average for this class of motor.

If starting by means of a potential starter, sketch *A*, Fig. 7, the torque conditions require the motor to be connected to the system on the 65 per cent tap, the current drawn by the motor (neglecting all line losses) equals $59 \times 0.65 = 38.4$ amperes, and the current drawn from the line is $59 \times 0.65 \times 0.65 = 25$ amperes. This current has a power factor practically the same as the full short-circuit current of the motor. Combining it vectorially in Fig. 4, with the 22 amperes load at 80 per cent power factor on the generator, it is found that the resultant current has a value of 44.75 amperes at 56 per cent power factor. Referring back to Fig. 2, curve *G* shows the relation between terminal voltage and excitation required to maintain the generator voltage with this load at this particular power factor. It can be seen that even with full field, and assuming the ideal condition of constant engine speed, the generator voltage cannot be maintained. The fact must not be lost sight of that the starting period of the motor is more or less of a temporary condition. Under usual favorable conditions it should not exceed one minute. In the present case, if it were possible for the engine to maintain its speed, the generator voltage would drop, with full field excitation, to 1,690 volts, and the period of starting would be lengthened to possibly three or four minutes. The whole situation would undoubtedly be further aggravated by a considerable drop in the engine speed, tending to a still further drop in the line voltage. Although the motor would probably start and come up to speed provided the torque requirements were not too great, it is seen that a considerable disturbance is created on the line. This is enough to cause a distinct flickering of any lights as well as to create the liability of knocking out any other induction motors that might be on the system, because it must be remembered that the output and torque of these machines varies as the square of the impressed voltage.

To alleviate the conditions as much as possible, some type of automatic voltage regulator in the field of the alternator would be necessary, for it is self-evident that hand regulation of the field would not act rapidly enough to meet the conditions of a rapidly fluctuating load. Even the addition of such a device, while tending to maintain an even terminal voltage under erratic loads, would not prevent subnormal voltages in case the load demand should exceed the limitations of the field. A solution of this particular problem, provided the

squirrel-cage motor cannot be started under light load or on a lower tap of the potential starter, can be found in the use of a slip-ring type induction motor. Unlike the squirrel-cage machine, which exerts a relatively small amount of torque with large currents at low power factor when starting, the slip-ring motor exerts a relatively large amount of torque with a minimum current at high power factor, under the same conditions. The torque, current and power-factor characteristics during

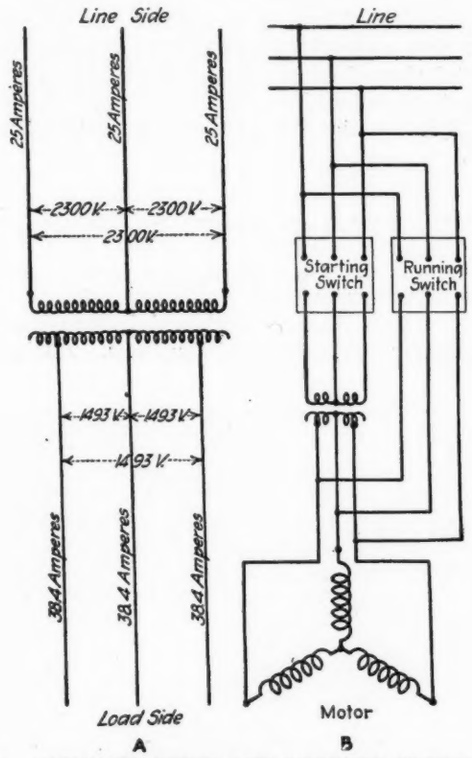


FIG. 7. MOTOR STARTING AND RUNNING CONNECTIONS

starting are dependent on the control apparatus used. Ordinarily, standard control apparatus is made so that the motor exerts 125 per cent of normal torque with 125 per cent of normal full-load current and a power factor, under these conditions, corresponding to 125 per cent running load power factor.

The resultant load current and power factor, assuming 125 per cent starting current at 90 per cent power factor, when replacing the squirrel-cage motor with the same size of slip-ring motor, is shown in Fig. 6. Transmitting this back to Fig. 2 curve *J* indicates that the generator will have no trouble in holding up its voltage provided the regulation of the engine is all that it should be.

Briefly summarizing, it may be stated that the examples and problems as given previously cover only the specific questions in point. Undoubtedly, problems entirely foreign to those cited may come up; different conditions may prevail; methods for relieving loads on squirrel-cage motors during starting might be used in some cases to get around the use of the slip-ring motor. Large plants with practically unlimited power resources encounter different problems from those of the small plant having small power capacity. A knowledge of their limitations is required for their successful operation. Application is not just a hit-and-miss proposition; it is coming to be more and more recognized as a very important subject.

Fuel Economy Outside the Boiler Room

By Rowland L. Tullis

A great deal has been written on the subject of economy in the boiler room, and much of it has no doubt been read, digested and put to good use by both operating and chief engineers. This is both fit and proper. It is absolutely necessary that the engineer do his best to produce steam as economically as possible, but it is a waste of human energy as well as mechanical energy for an engineer to produce economically and later allow it to go to waste or use it uneconomically. In too many cases this is exactly what happens. An example of this is shown in the case of the chief engineer of a large hotel who made such a mistake, and whose mistake was rectified by another who went outside the engine room to look for trouble.

The hotel had originally consisted of one four-story wooden wooden-framed building of about 160 rooms. Although the building could not be called modern in any respect, the management seemed to make money out of it and soon acquired a six-story building next door. Finally, they erected a thirteen-story, modern fireproof structure on the corner, making altogether a hotel of more than a thousand rooms. A large, modern hotel power plant was installed in the new building, designed to supply heat, light and power for the entire property, consequently the power plant in the old building was shut down, and the chief engineer was transferred to the new plant with an increase in salary.

This man was considered a competent and reliable engineer by his employers. He had been with them for many years, and they had been well satisfied with the service that he rendered. Two years ago he died and a new man was hired. As is usually the case, the hotel owners entertained some grave misgivings about the selection of a stranger to fill the old chief's place.

The new chief engineer was a man of long and varied experience and had come well recommended. Like every ambitious engineer taking a new position, he was on a constant lookout for a chance to better the service, decrease operating expenses or increase the economical operation of the plant. There is no doubt that he was looking for a chance to make a reputation for himself and thereby increase his monthly compensation.

First he made a careful survey of the boiler room, which contained four 250-hp. water-tube boilers. He found that the boilers were fired properly, that the settings were in almost perfect condition and that the draft was closely regulated. An evaporation test showed that the old chief had been evaporating as much water as was humanly possible with the grade of fuel that was burned. There was absolutely no chance to make a reputation for himself in the boiler room, so the new chief turned his attention to the engine room. He examined the engines, put his indicator to use, and even went so far as to take off the heads and examine the cylinders, pistons and rings, but he found nothing that would give him an opportunity to make improvements. He was about to give up in disgust as it was evident that the old chief had been wide awake. Finally he decided to go over all the steam traps and the heating system in the building in a last endeavor to find some place where he could make an appreciable saving in steam. He didn't have far to go until he began to find troubles and opportunities a-plenty.

As is usually the case in a hotel power plant, the exhaust lines and drain lines from the engines, steam separators and traps were run in tunnels or trenches beneath the engine-room floor, the trenches being covered with diamond-plate. The casual observer would never suspect that beneath this diamond-plate flooring was hidden a maze of pipe lines, valves and traps. Unless something went wrong the average engineer would never go to the trouble of lifting the plates to see what was under them.

The engines had steam jackets provided with drains at both ends. These led to traps which discharged into the exhaust line from the engines. The chief found the traps on all the drain lines in a bad state of repair. Consequently, live steam was blowing through into the exhaust line. A number of the traps were shut off entirely, the bypasses were open and steam was being wasted where it couldn't be seen and where it would be least expected. Similar trouble was found on the kitchen and laundry lines. Many of the traps were full of mud or sediment which had been carried over from the boilers when they carried over water. The chief saw to it that every trap in the building was thoroughly cleaned and overhauled, and valves and seats were ground or replaced with new, where necessary.

Next he discovered that they were using a great amount of live steam for heating purposes throughout the building in cold weather, although the exhaust from the engines should be sufficient under all conditions. A few days later he took an entire day to go over the heating system with the house plumber, who was thoroughly acquainted with all the details of the system. The heating system of the new twelve-story building was found to be almost perfect. It was a modern two-pipe vacuum system with an individual trap on each radiator; steam was supplied to the radiators at from four to five pounds pressure, and returns were cared for by a vacuum pump in the engine room. The house plumber explained that he seldom had any trouble with this section of the hotel, but complaints were pouring in every day about the old section. It was almost impossible to keep the rooms warm with the present arrangement of heating.

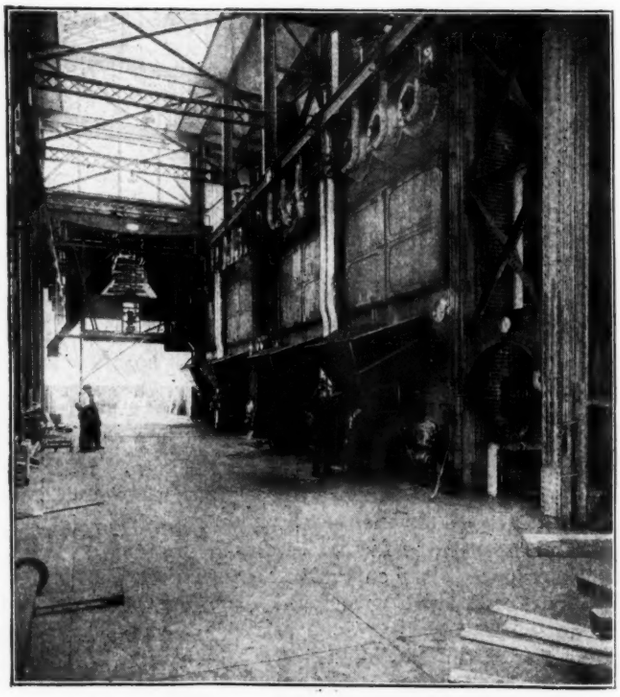
The oldest part of the hotel, consisting of about four hundred rooms, was divided into two separate buildings each with its individual heating system. One section of the old building was equipped with the single-pipe system; that is, the steam was supplied to the radiators and the condensation returned through the same line to the basement of the building, where it was received by a master trap and dumped back to the feed-water heater in the engine room. It was about a hundred yards from the basement of this building to the new engine room. The whole arrangement was obsolete and sluggish in action. Occasionaly, the master trap would refuse to work and the entire system would fill with condensation. Live steam would then be turned on, but would do no good as long as the condensation was in the system.

The heating system of the other section of the old building was even more obsolete in design and arrangement. There was a large hot-water heater of the horizontal-tubular type in the basement, and a small motor-driven centrifugal pump received hot water from this heater and circulated it through the radiators. The water was heated by a combination of live and exhaust steam, and the 1¼-in. live steam inlet was usually open.

After making a detailed survey of the situation, the chief made a lengthy report to the office and had a talk with the hotel owner. In a few words he put it squarely up to him that it would cost about two thousand dollars to remodel the heating system. Most of the old piping could be used, but return lines and traps would have to be supplied for all the radiators. The owner kicked a little at first on the expenditure, but the engineer was adamant and finally got what he was after. The two-pipe vacuum system was finally installed and put into operation. There is no further need of live steam, seldom does a complaint come from the old building and the chief showed a saving in fuel oil last year of over twelve thousand dollars. His yearly remuneration is now $3,500, while his predecessor received a scant $2,000.

Good Lighting in Power Stations

There used to be a time when a power station was considered naturally black inside and outside. Owners perhaps thought that coal-blackened firemen fitted better into a kindly atmosphere of blackness. But that day has gone by. Power stations should be as light as a factory or a dairy lunch room. This is not only for the appearance of the station, but because good lighting has proved economical in inciting efficient, cheerful, safe work by the men in the station. The importance of good lighting has been proved everywhere in factories and it is no less important in power stations. Good lighting pays dividends through contented men and neat scientific operation. That is why power-station engineers and directors arrange for it.



BOILER ROOM, LOOKING EAST

The photograph shows the interior of the boiler room of the New Bedford Gas and Edison Light Co.'s power station built by Stone & Webster. Here excellent lighting is incorporated into the design.

The Emmet Mercury Boiler

A Binary-Vapor Power Plant Using Mercury Vapor and Steam

A brief account of a plan to use mercury vapor and water vapor for the generation of power appeared in the March 31, 1914, issue of "Power." That article was an abstract of a paper presented before the American Institute of Electrical Engineers by the inventor, W. L. R. Emmet. Further development work has been done on the apparatus, although necessary wartime activities have interfered somewhat. In spite of such interference much experimental information has been acquired.

IT IS a well-known fact that the efficiency of any heat engine may be increased by increasing the temperature range through which it works. There are two ways to do this. One is to lower the temperature of the exhaust, and the other is to raise the temperature of the supply. The minimum exhaust temperature is, of course, limited by the temperature of the available cooling water. The temperature of the supply is limited by the temperature of combustion of the fuel, and in a steam engine is further limited by the properties of steam. At reasonably high temperatures the pressure of steam becomes too great for convenient commercial operation.

To overcome this difficulty, Mr. Emmet has designed a binary-vapor plant using mercury vapor and water vapor. Mercury boils and condenses exactly like water except that its density is much greater and its boiling temperature much higher. For example, at atmospheric pressure mercury boils at 677 deg. F. and condenses in a 28-in. vacuum at 455 deg. F. The corresponding temperatures for water would be 212 deg. F. and 101 deg. F. respectively. Briefly, Mr. Emmet's scheme is as follows: Mercury is boiled in a boiler similar in principle to, but differing greatly in detail from, an ordinary steam boiler, and the mercury vapor produced is used to run a turbine. The exhaust from the mercury turbine is condensed in a form of surface condenser, which is also a boiler. The heat given out by the condensing mercury vapor makes steam of the cooling water, and this steam may be used to drive another turbine or for any other purpose for which steam may be required. The chief difficulties seem to be the large amount of mercury needed and the danger of leaks, as the mercury vapor is very poisonous.

The illustration (see insert) represents diagrammatically the elements of Mr. Emmet's apparatus. The products of combustion from the furnace pass upward through part of the tubes which form the heating surface of the mercury boiler, and then forward among the remainder. These tubes are connected to the lower mercury chest, which might be called the mud drum in a steam boiler and to the mercury header corresponding to the steam drum in an ordinary boiler above. Mercury vapor at about 10 lb. gage pressure is collected in the header and passes through the pipe shown to the mercury turbine. Owing to the high density and low spouting velocity of the mercury vapor this turbine may be a single-stage machine, of reasonably low speed, and may have short buckets. The wheel may be placed inside the mercury condenser for simplicity.

The mercury condenser consists of a tank, as shown, supporting another tank marked "Steam Drum." A number of straight tubes extend from the bottom of the steam drum down into the condenser. The exhaust from the mercury turbine is condensed on the surface of these tubes, and as the boiling point of the mercury at 28 in. vacuum is 455 deg. F., steam may be generated inside the tubes. Circulation in the tubes is provided by smaller tubes inside them, leading from the steam drum, which corresponds to the upper drum of a water-tube boiler. The steam that is generated in this condenser-boiler is led through the pipes marked "To Superheater" through the superheater and finally through the steam main to wherever the steam is to be used. The steam condensate, whether from a steam turbine or engine, heating system or manufacturing process, is returned to the condensed steam receiver. From here it is pumped to the feed-water heater, which is really an economizer. This feed-water heater is shown in the illustration directly below the mercury condenser. From here the water returns to the steam boiler, thus completing its cycle.

The mercury condensate is drained from the bottom of the mercury condenser to the lower mercury header and thence to the mercury boiler. The high density of mercury renders a feed pump unnecessary, as by setting the condenser above the boiler the latter can be fed by gravity.

The foregoing covers the general principle of the apparatus, but certain refinements seem necessary for its practical application.

The quantity of mercury that would be required if an ordinary steam-type boiler was used would make the cost prohibitive. For this reason a special type of boiler had to be designed to give a maximum heating surface and at the same time require a minimum amount of mercury. The first designs for the boiler proper called for the use of flattened tubes for the elements of the boiler. This shape of cross-section gives much more heating surface with less volume of liquid than a circular tube would give. The later designs call for sections of similar shape, but made up of sheet metal. Experiments are now going on to determine the necessary proportions of such elements to provide for proper liquid circulation and release of vapor.

The question of preventing leaks was a serious one, as even a small amount of mercury vapor leaking into the engine or boiler room would poison all the operators. Great care was exercised in the design and in the construction of the fittings and pipes containing the mercury vapor, the mercury parts of the outfit are run at low pressure so that there is a minimum tendency to leakage and means are provided to condense and save all mercury which leaks from joints. The diaphragm valve, which is shown on the mercury-vapor pipe near the mercury turbine, is simply a safety relief valve.

This safety valve, instead of discharging into the open air, is arranged to discharge into the mercury condenser.

The temperature of the mercury in the boiler is so high that the temperature of the flue gases leaving the tubes would be entirely too high for conomical operation if they passed directly to the stack. To avoid such losses the flue gases, after leaving the tubes of the boiler, pass over a mercury preheater (not shown in the illustration), then over the steam superheater, and finally over the feed-water heater or economizer, and then to the stack. In this way the temperature of the gases entering the stack can be made as low or even lower than would be possible with a steam boiler plant of the ordinary type.

It should be remembered that a steam turbine is not an essential part of this device, but the intention is to afford a substitute for the existing boiler. The steam may be used as it now is for any desired purpose. The mercury acts as a conveyor of heat from the furnace to the steam and incidentally delivers a certain amount of power as a byproduct. A large part of the power generated in the mercury turbine is net gain, as it comes in part from heat that would otherwise be rendered unavailable by the great drop in temperature between the furnace gases and the steam.

Another advantage of this process is that the interior of that part of the boiler exposed to the fire is always perfectly clean. Also the boiler in which steam is made is subject to no large temperature differences.

Mr. Emmet has claimed that by the addition of this device to an assumed good modern power station with an increase of 15 per cent in the amount of fuel used, the same amount of steam can be supplied to the steam turbine as under present conditions, and the mercury turbine will generate power equal to about 66 per cent of the power generated by the steam turbine. This results in a gain in station capacity of approximately 66 per cent with an increase of only 15 per cent in the amount of fuel required.

The experimental equipment was in operation for a short time last summer with over 1,000 kw. load on the mercury turbine, and its operation showed that the economies predicted were fully realized.

Trouble Hunting in Refrigerating Plants

How a Faulty Gate Valve in the Brine-Circulating System of a Southern Packing House Plant Causes a Freeze-Up of Nearly the Entire System

By J. C. MORAN

IN A SOUTHERN packing-house plant there were two 75-ton machines, one of them working direct expansion on the sharp freezers and other low-temperature work, while the other was run on a brine cooler of the triple-pipe type, which cooled the brine used for cooling the chill rooms and other high-temperature work. The engineer had originally been a steamfitter around the plant, and when the old engineer died he got his job. The fitter had been in charge about three months when I came to town, and soon he came over and got acquainted. He had trouble in keeping the temperatures down, and he came to me, seeking advice. After looking the job over, I set him straight and gave him a few pointers on how to handle the machines. As a consequence he began to call regularly whenever anything went wrong that he could not at once remedy.

One Monday morning he came in on the run and asked me to come over right away. I went back with him. It seems that the trouble started during the night, yet no one could find anything wrong with the machine, which was the one working on the brine cooler and seldom caused any trouble. First the machine began to freeze. The night man had pinched back on the expansion valves until they were almost entirely shut without helping things in the least. At the same time the suction pressure had dropped until it was somewhere around 5 in. vacuum with the machine running slow. The condenser pressure had dropped to less than a hundred pounds while normally they carried about 140 lb. at this time of the year. In addition the machine had started to pound very hard as it passed over the crank-end center. The thermometer on the inlet registered about 35 deg., while the temperature indicated on the outlet from the brine cooler was around zero. Generally the temperature of the outlet brine was between 18 and 20 deg. and the inlet temperature, which was also the temperature of the brine returning from the chill rooms, was generally 25 deg. or lower.

The brine was circulated by a centrifugal pump, the suction of which was connected to the returns from the chill rooms and the discharge of which was connected to the inlet of the brine cooler. This was working about the same as usual, except that the discharge pressure was considerably higher than it used to be. Apparently, there was something wrong with the brine circulation or there would not have been such a large difference between the inlet and outlet temperatures of the brine as it circulated through the cooler. The engineer suggested that we take a trip up to the coolers with a lantern, and we did so as the first step in the investigation. The chill rooms were cooled by a curtain system located above the coolers. The brine was delivered into distributing troughs hung near the ceiling of the cooler, on which were hung curtains over which the brine trickled down to the floor of the curtain deck, thence running into gutters to the return pipes to the centrifugal pump in the engine room. When we got on the curtain deck, there was not a sign of brine circulation anywhere, and as far as I could see the pump might just as well have been shut down.

So we went back to the engine room in a hurry. It was now plain that there was no brine circulating through the brine cooler and that this was the reason the machine froze, because there was no heat to evaporate the ammonia fed into the cooler. So it came back to the machine in about the same condition it left the expansion valve.

Judging from the engineer's statement that the trouble had started during the night, I suspected that the brine cooler was frozen by this time. Accordingly,

I went to try one of the individual valves on each stand of the cooler to see if I could shut it. It refused to budge, and I was now sure that the brine cooler was frozen.

We pumped out the ammonia and removed the return bends. Sure enough, every one of the stands was frozen

return bend of each stand on again, I decided to test everything and make sure that every stand was clear so that we would not have the same trouble over again, or that one or more of the stands might not freeze while the others kept on working. To do this I opened the suction and discharge valves on the pump, believing the

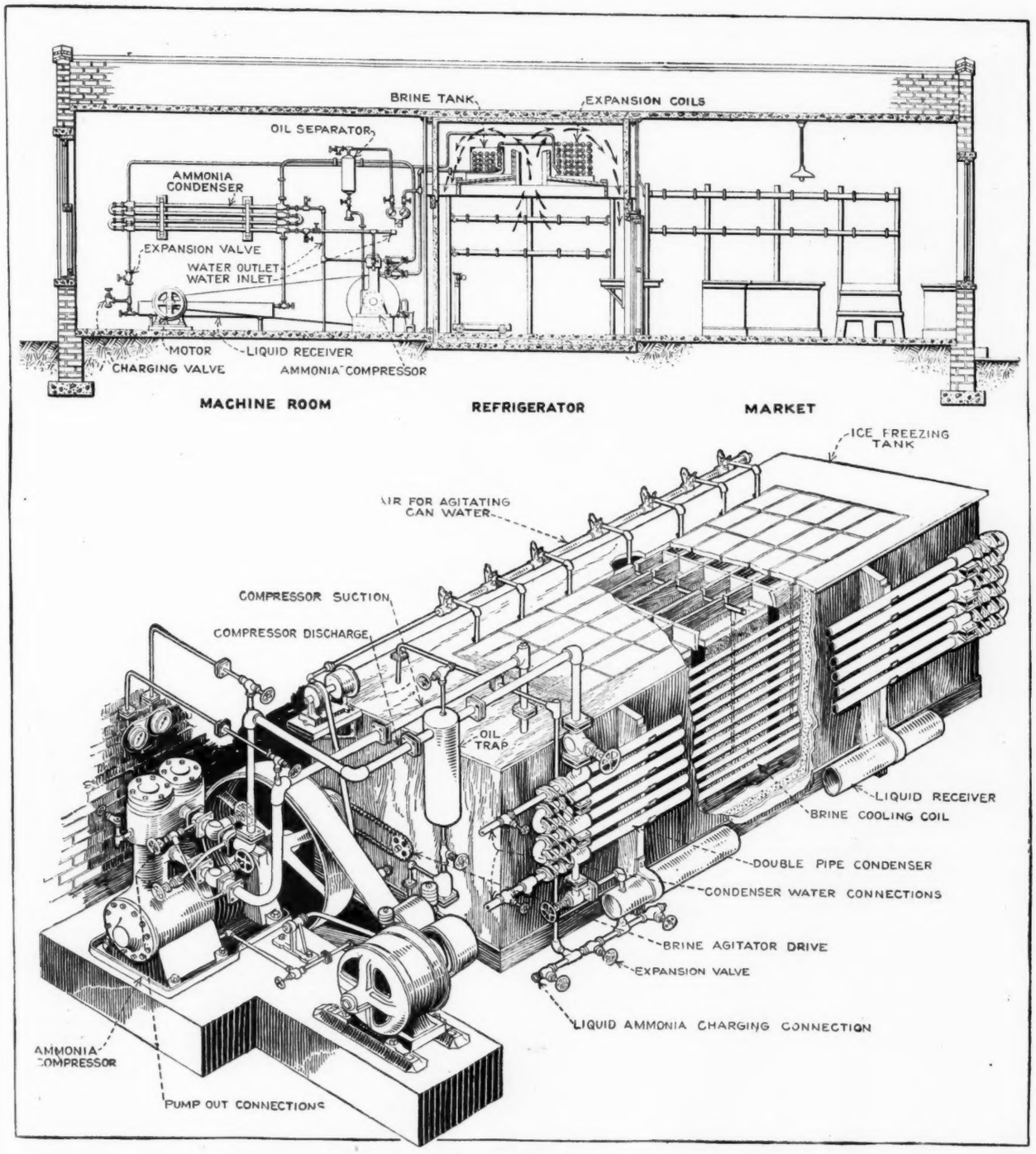


FIG. 1. TYPICAL LAYOUTS OF REFRIGERATING AND ICE-MAKING PLANTS

solid. We got a hot-water hose with a steam and water connection rigged, and played steaming hot water all over it for several hours. Also we rigged a smaller steam lance which we used for thawing out the inner pipes. Finally, we got the thing thawed out. Luckily, none of the pipes burst. After we had all but the last

pressure on the suction line, due to the chill rooms and gutters being located about 40 ft. above the engine room and the cooler, would be sufficient to force the brine through the cooler and clear out small obstructions that might be present. I was surprised to find that this did not work. I looked around the pipe line and cooler think-

ing some valve might be shut, but all were open. Not having any success with this method, I next started the pump, feeling sure that the pressure produced by the pump would start things. It did not. One of the men finally called attention to the high pressure on the pump, which could be expected if there was an obstruction some place in the line. So we began to look for trouble in the discharge line between the cooler and the pump. We came to the gate valve used as a stop valve in the discharge line, just ahead of the pump. After opening and closing it a number of times we concluded that it worked too easily. So we removed the bonnet, and sure enough, the gate had dropped and shut off the line; this was the true cause of all the trouble.

The shutting off of the circulation of the brine through the cooler caused this to freeze, and as practically no work was then being done in the cooler, the liquid ammonia did not evaporate, and so came back to the compressor in liquid form, freezing the machine With little or none of the liquid evaporated there was practically no gas generated, and of course the suction pressure went down. With the large amount of liquid coming back, the machine froze, got very cold, and this in turn contracted the piston rod so that it was a little shorter than usual. In adjusting the bearings the piston had been shifted so that it came very close to the crank-end head when the machine worked at normal temperature. When it got real cold, the contraction of the rod was sufficient to bring it up against the head, and this caused the knock. After the cooler was thawed out and the gas came back at the proper temperature, there was no knock, but as a precaution against future trouble we backed the rod out of the crosshead a fraction of a turn so as to get the clearance at both ends of the cylinder.

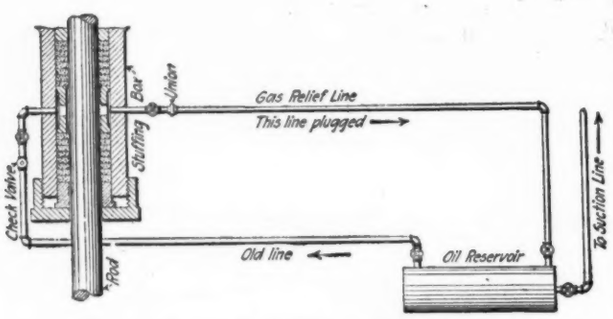


FIG. 2. THE GAS RELIEF LINE WAS PLUGGED

The Stuffing Box Bothers the Engineer

Some weeks later I dropped in for a visit and found the engineer nursing the stuffing box on the machine working on the brine cooler. This stuffing box had been giving trouble for a long while. We shut the machine down for a few minutes, and first calipered the rod, thinking that this might be smaller in diameter in the center than at the ends; but the difference was so small that it could not have been the cause of the trouble. I had run a number of rods where the difference was much greater. I have in some cases run rods that were $\frac{1}{8}$ in. smaller at the center than at the ends without serious trouble. The difference in this case was but $\frac{1}{64}$ inch.

We checked the adjustment of the crosshead shoes to see if they were adjusted so that the rod traveled in a straight line. A lot of trouble is often met from this cause, the shoes being so adjusted that the rod is thrown up or down at the end of the head-end stroke, and caused to travel up and down in the stuffing box, and of course it is next to impossible to keep the packing tight. There was nothing wrong with the adjustment, however, in this case.

I was puzzled by this time when I happened to think of the gas-relief line from the stuffing box, as shown in Fig. 2. The gas relief line, it will be seen, connects to the top of the oil reservoir which feeds the oil to the stuffing box through the pipe connected to the bottom. The pipe leading from the top connects to the suction line of the compressor, which allows the gas that comes to the oil reservoir from the stuffing box to pass on to the suction line. It also insures suction pressure on the reservoir, and no more, while the gravity head of the oil is about right to keep the oil feeding well through the stuffing box.

There was a union in the line near the stuffing box, and this we disconnected. The pipe was obstructed in both directions with old packing and gummy oil, and to get it out we had to take the whole line down in sections and blow each out with air. For some of them we had to fix up long packing hooks and dig out part of the obstruction until we were able to get the rest free to start.

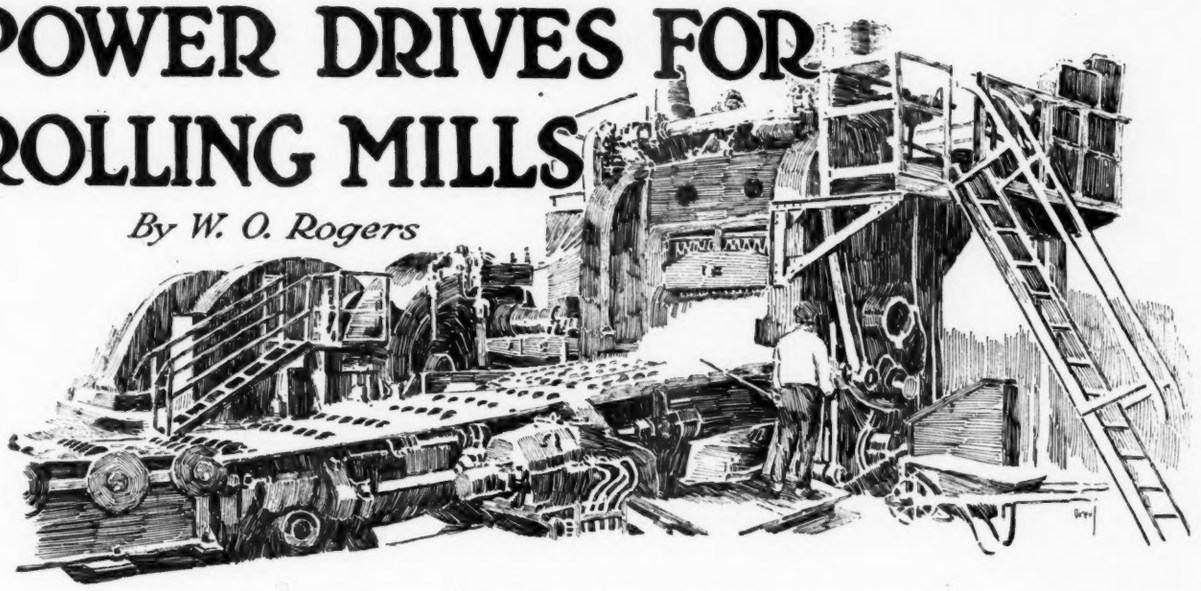
After we had the pipe cleaned, connected again and the compressor started, there was no more trouble with this stuffing box. The main purpose of this connection is to let whatever gas gets by the first section of packing escape back to the suction line, and as a consequence there is never more than suction pressure on the front section of the packing, of that part in front of the lantern. When the line got blocked, the pressure accumulated in the lantern until it was probably the same as the discharge pressure, and of course there was a lot more trouble to keep the stuffing box from leaking under these conditions.

The first step in the process of obtaining alcohol from wood is digestion at a pressure of 115 lb. for fifteen minutes in dilute sulphuric acid, says *The Engineer*. The cooked wood is transferred to a series of cylindrical cells so connected that water may be passed through them in rotation. From these cells is obtained an extract called "acid juice," which holds in solution practically all the sugar mixed with other water-soluble ingredients. This liquid is neutralized, either with high-grade limestone or slaked lime. Calcium sulphate is produced, which requires about twelve hours for settling. The clear juice is drawn off and cooled to about 88 deg. F., yeast added, and the fermentation carried on in the usual way. The juice must be slightly acid, as ordinary yeasts do not operate well in alkaline solutions. By distillation the alcohol is obtained, and may be readily refined.

Multiple-stage reciprocating compressors are used when high pressures are desired. In this type of compressor the air receives an initial compression in one cylinder. Passing through an intercooler, it is compressed in a second cylinder and so on until the desired compression is accomplished. Because of efficiency in cooling and because clearance losses are reduced, multiple-stage compressors are the most efficient. Theoretically, the more stages the higher the efficiency, but the size and cost of machinery and also frictional losses limit the number of stages to four at the most.

POWER DRIVES FOR ROLLING MILLS

By W. O. Rogers



The latest development in power drives for rolling mills is the direct-current reversible motor. Those described in this article are of 5,000 and 15,000 hp. capacity and are used to run reversing blooming mills.

ONE of the principal electrical developments of recent years in steel-mill power equipment has been the reversing-mill motor, and it is safe to say that of all the applications of electric motors none is subject to more severe conditions than those driving reversing mills. The mills of recent design include reversing roughing stands and tandem arrangement of mills, which gives the plant greater flexibility of size, of production and increases its tonnage output with a decrease in power requirements. Some of those included are plate mills, strip mills and structural mills. In a former article several large reversing engines were illustrated, but unlike the steam drive, which calls for an unusual steam supply for a reversing mill, the reversing motor drive acts as an equalizer for the three-high continuously operated mill because the power taken from the main feed line is uniform in the former and intermittent with high peak loads for the latter type of mill. Reversing motors are frequently subjected to overloads several times their continuous capacity, and they must carry these overloads throughout the full range of speeds, from rest to maximum speed in both directions when driving the mill or operating as a generator in braking; that is, coming to a stop.

When an ingot is put through the rolls for the first few passes, the piece, being short, requires less than one revolution of the rolls to carry the metal through them. In order to force the rolls to bite the ingot, as well as to prevent them from throwing the piece out on the table after making the pass, it is necessary to keep the speed down. With so short a piece of metal high roll speed is not necessary and would only interfere with the quick handling of the equipment. However, after the piece has lengthened out, the roll speed is increased and the remainder of the passes can be made at high speed. Owing to the unusually severe conditions under which they operate, rolling-mill motors are designed with liberal factors of safety so as to permit of rapid acceleration and reversing. In reversing-mill motors the speed is adjustable over the full range from rest to maximum speed in either direction of rotation, and, when so adjusted, is practically independent of the load. This type of motor is capable of carry-

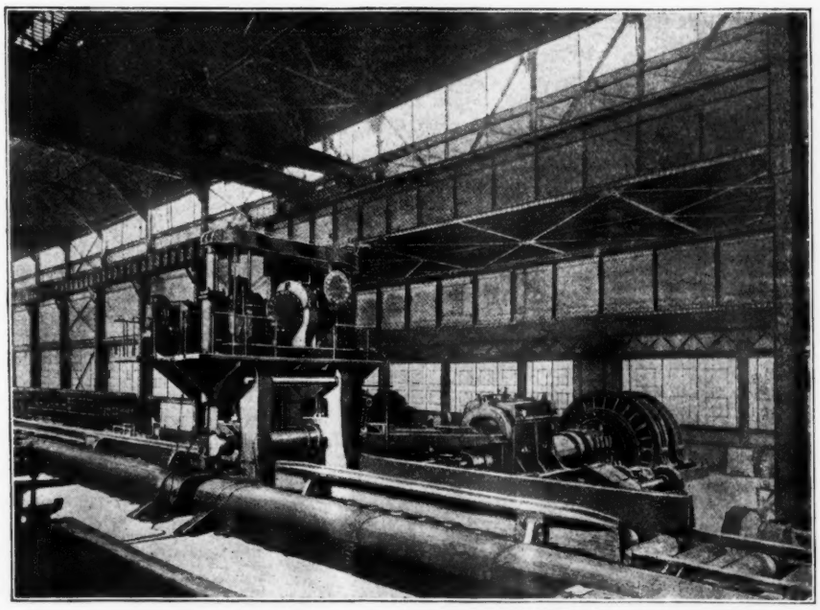


FIG. 1. A 15,000-HP. DIRECT-CURRENT REVERSING MOTOR DRIVING A 35-IN. REVERSING BLOOMING MILL

ing extreme overloads at all speeds during acceleration, driving the mill at full speed or during regenerative braking in slowing down the mill at the end of the pass. Another characteristic of this type of motor is that the inertia of the revolving parts is low, so as to permit of rapid acceleration and reversal, which is necessary because the greater part of the time consumed in breaking down an ingot is taken between passes.

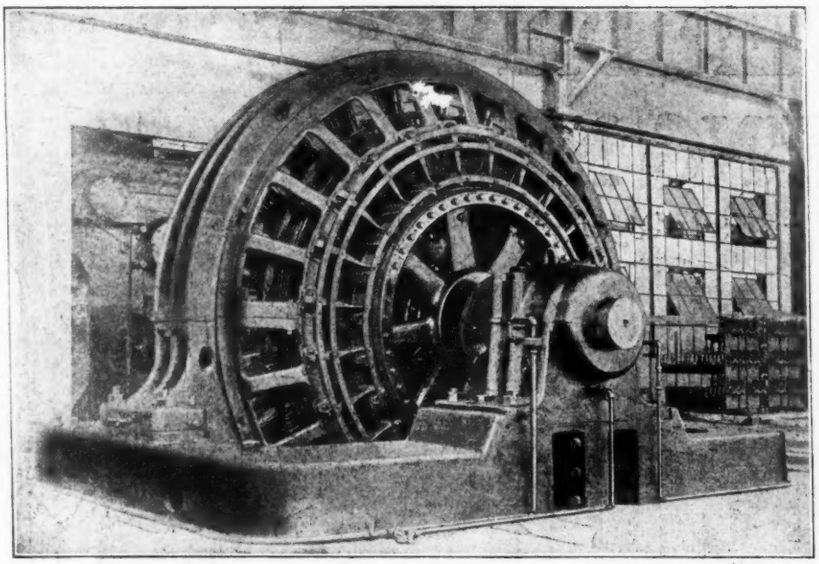


FIG. 2. SINGLE UNIT, 8,000-HP. REVERSING MOTOR DRIVING A 27-IN. UNIVERSAL MILL

The Ward-Leonard control is used. Briefly, this system consists of a constant-speed motor driving a generator that supplies current to the motor whose speed is to be regulated. This motor-generator set is placed between the variable-speed motor and the system supplying the current. The driving motor of the motor-generator set is usually of the wound-rotor induction type coupled to a direct-current generator, the machine carrying a flywheel on the shaft.

The excitation of the direct-current generator is arranged to vary over a wide range by means of a rheostat in its field circuit. The generator armature and the motor armature by themselves constitute a circuit which is not interrupted in service. Manipulation of the field rheostat and switch gear in the exciting circuit of the generator, and also the speed and direction of rotation of the variable-speed motor, are under control at all loads.

The flywheel of the motor-generator set serves to smooth out the peaks from the reversing motor's load, which are extremely high and of short duration, and which, without a flywheel, would follow back to the main power system.

When the motor of the motor-generator set comes up to speed, it stores up energy in the flywheel, and when a heavy current is demanded by the roll motor, the motor of the motor-generator set is automatically

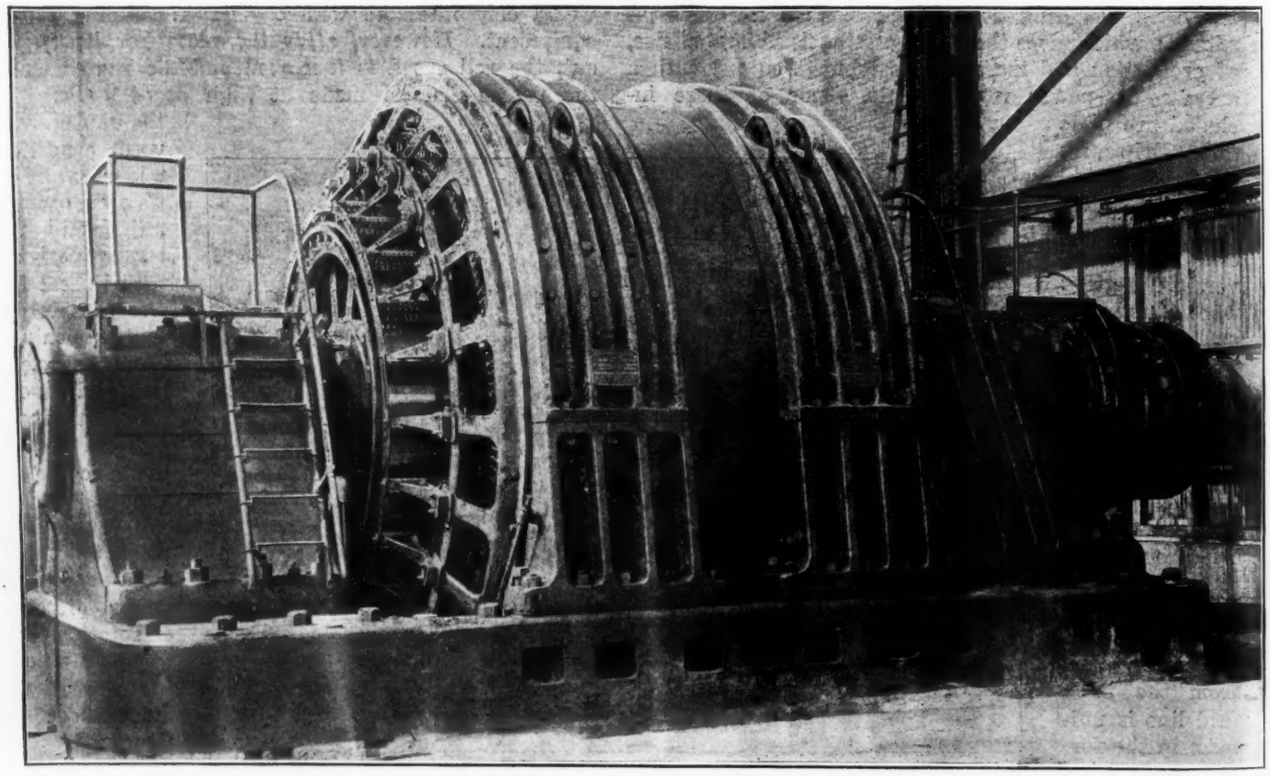


FIG. 3. A 5,000-HP. DOUBLE DIRECT-CURRENT REVERSING MOTOR DRIVING A 36-IN. BLOOMING MILL

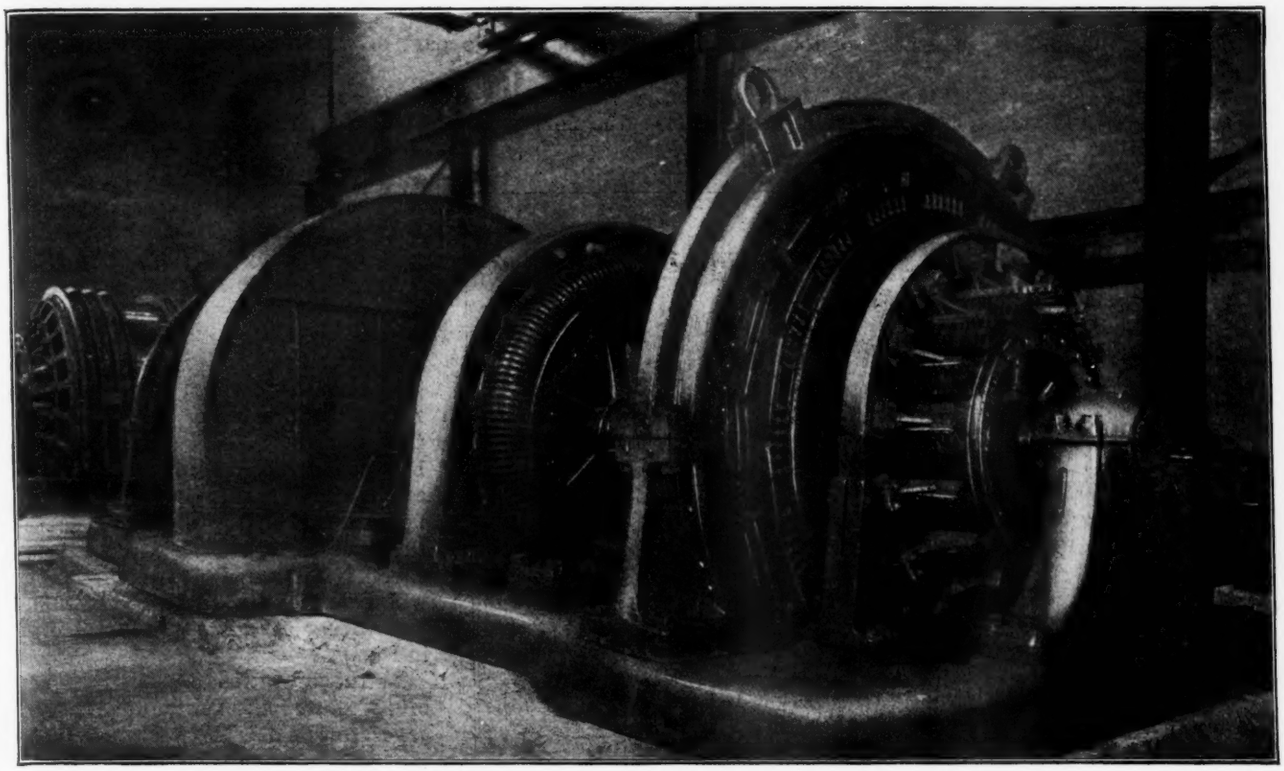


FIG. 4. MOTOR-GENERATOR SET CONSISTING OF A 3,000-HP. INDUCTION MOTOR AND TWO 2,000-HP. DIRECT-CURRENT GENERATORS

slowed down by means of a slip regulator. As the motor of the motor-generator set slows down, the flywheel carries a part of the load. When the peak load is removed or, in other words, when the ingot has passed through the rolls, the motor of the motor-generator set speeds up again and returns energy to the flywheel. In this way the load on the alternating-current motor is greater than that on the roll motor when the latter is driving light load, and is less when it is carrying a peak load, as when the ingot is making a pass. Automatic slip regulators are used to regulate the speed of the induction motor and consequently the rate

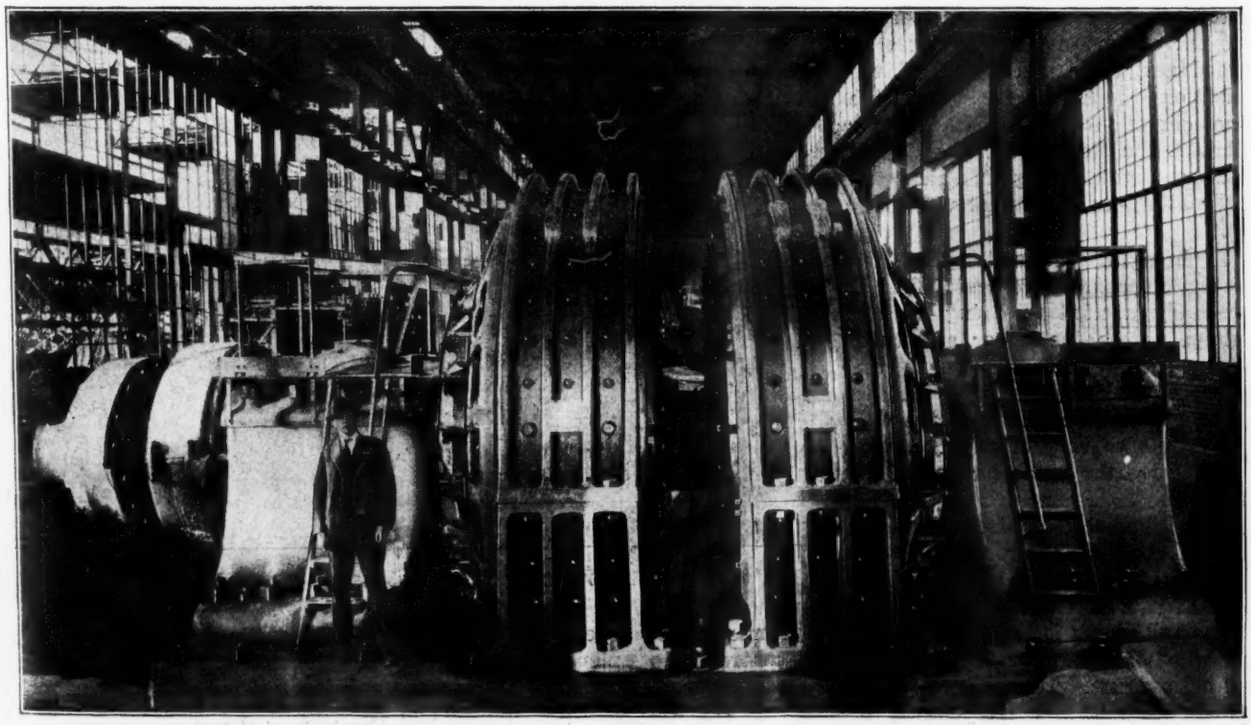


FIG. 5. SIDE VIEW OF A 5,000-HP. DIRECT-CURRENT REVERSING MOTOR

at which energy is delivered to the flywheel, which permits of obtaining better equalization of the motor load. The slip regulator consists of a liquid rheostat with three stationary electrodes connected to the three phases of the rotor on the induction motor driving the motor-generating set. Three movable electrodes are connected to an arm that is mounted on the shaft of a small torque motor, the other end of the arm being provided with a counterweight. This small motor receives current from series transformers in the main line (see Fig. 9). When the current in the line increases, the motor pulls the electrodes apart and in so doing introduces resistance into the rotor circuit of the alternating-current motor. This reduces its speed and throws the peak of the load on the flywheel. When the line current decreases, the motor allows the electrodes to come nearer together again, and the alternating-current motor speeds up.

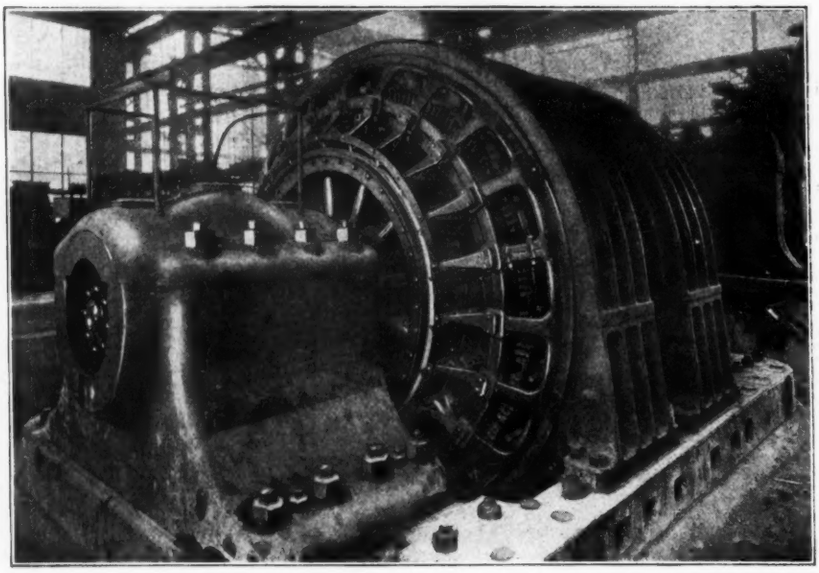


FIG. 6. A CLOSE-UP VIEW OF THE COMMUTATOR END OF THE 5,000-HP. MOTOR

In bringing the motor-generator set up to speed, the generator field is gradually excited to bring up the voltage across the motor armature, which causes it to revolve in the direction indicated by the master switch. The speed curve of the mill motor follows very closely the voltage curve of the generator up to full-field speed. From this point the speed is increased by decreasing the field of the mill motor, which is accomplished by means of the operator's drum controller.

The roll motor is brought to rest by dynamic brakeing when the operator brings the master controller to the off position. This reduces the voltage of the generator below that corresponding to that of the roll motor, and during that period the generator acts as a motor and tends to speed up the flywheel. By this means a large part of the accelerating energy is reclaimed.

The various operations, including the variation of the field strength, etc., are accomplished by means of magnetic contactors, which are also arranged to insure a proper sequence of operation with proper interlockings for safety and assist materially in accomplishing the desired rapidity.

It will be seen that the control of the roll motor is effected by varying the strength and direction of the field or exciter current in a direct-current generator. Increasing the field current of the generator also increases the voltage of the current that is being delivered to the roll motor, and the motor will speed up. If the field current is decreased, it produces the opposite effect, and if the field current is reversed, the roll motor will revolve in a reverse direction. The wiring of this system is shown in Fig. 9.

In the operation of the dynamic brake to stop the roll motor, if the generator field is so weakened that the voltage generated is less than that generated by the roll motor, the motor acts as a generator and attempts to drive the motor-generator set; and as this acts as a powerful drag on the roll motor, it slows down, as with the application of a mechanical brake.

Several examples of reversing-mill motors are depicted in the illustrations. In Fig. 1 is shown a two-unit 15,000-hp. Westinghouse reversing motor that operates a 35-in. reversing blooming mill at the Mark plant of the Steel and Tube Company of America, Indiana Harbor, Ind. It is of the direct-current type and operates at 600 volts. Fig. 2 shows a single-unit 8,000-hp. 600-volt motor operating the 27-in. universal

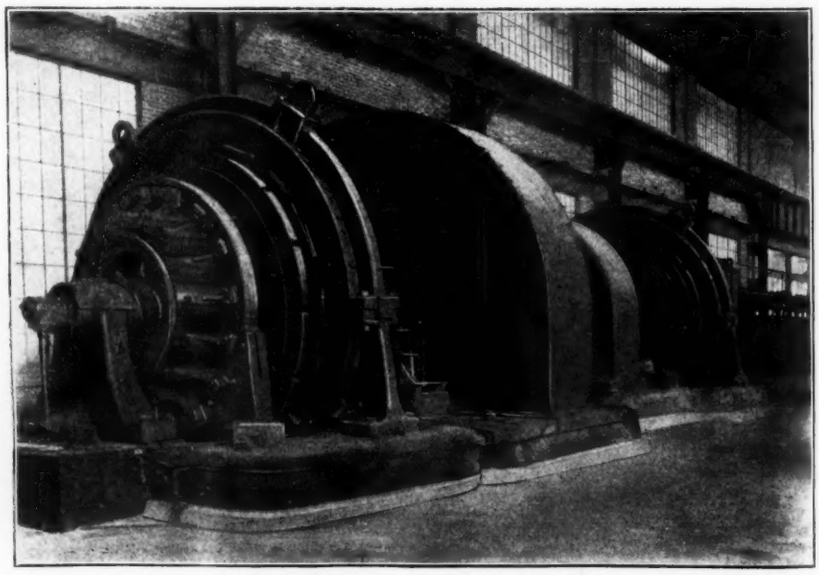


FIG. 7. ANOTHER VIEW OF A MOTOR-GENERATOR SET

plate mill at the same plant. This mill has established an unusual production record, having rolled in one month 17,393 tons of plates averaging less than $\frac{3}{8}$ in. in thickness.

I was fortunate in obtaining permission to go through the plant of the Trumbull Steel Co., Warren, Ohio. This plant was right up to date with the leaders in the number and capacity of electrically driven rolls, having several units with a continuous capacity of 17,100 hp. What is said to be the fastest mill in the world is their continuous hot-strip mill, which is driven by adjustable-speed induction motors.

The 36-in. reversing blooming mill at this plant is driven by a General Electric 5,000-hp. from 50 to 120 r.p.m. two-unit reversing motor using 500-volt direct current. This motor (Fig. 3) is directly connected to the mill and has a continuous torque of 656,000 ft.-lb. and 2,000,000 intermittent.

The motor-generator set that supplies energy to the 5,000-hp. reversing motor is shown in Fig. 4. It consists of a 3,000-hp. induction motor using 2,300-volt 60-cycle three-phase current and has a speed of 360 r.p.m. The two generators are of 4,000-kw. total capacity and generate 500-volt direct current. The flywheel weighs 50 tons.

Another interesting installation of the same capacity was found at the Sparrow's Point, Md., plant of the Bethlehem Steel Co. This General Electric double

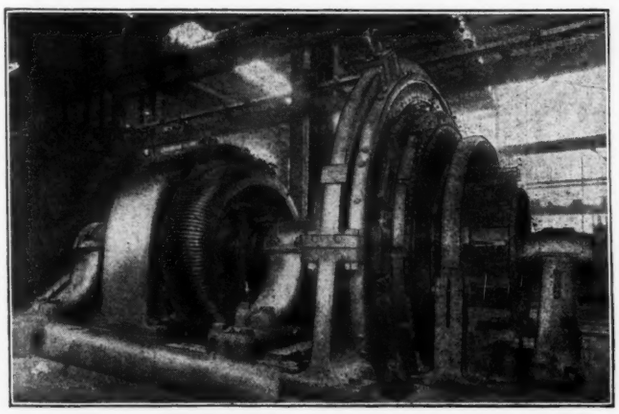


FIG. 8. CLOSE-UP VIEW OF THE MOTOR AND ONE GENERATOR

unit, shown in Fig. 5, develops 5,000 hp. when operating at speeds varying from 50 to 120 r.p.m. It is used to drive a 40-in. reversing blooming mill. A close-up view of the commutator end of the motor is shown in Fig. 6. An idea of the massive construction may be had by the comparison of the man standing by the bearing, Fig. 5.

The motor-generator set used in conjunction with this reversing motor consists of two 2,000-kw. 600-volts per unit direct-current generators driven by a 3,000-hp. 6,600-volt 25-cycle induction motor, Fig. 7. The speed is 375 r.p.m. and the flywheel weighs 50 tons. Fig. 8 is a close-up view of the motor and one of the generators.

A 17,500-hp. Westinghouse reversing motor at this same plant is used to drive a 60-in. universal plate mill. It has a speed up to 100 r.p.m. and uses 700-volt direct current. So far as known, this is the largest reversing motor in this country. Two units of 19,000 hp. have recently been installed at a steel works in England. One drives a 36-in. roughing mill and the other a 34-in. similar mill. The speed is 60 to 140 r.p.m. and the units operate on the Ward-Leonard-Ilgner system. The motor comprises three units coupled together and mounted on a combined bedplate. The complete machine weighs approximately 300 tons.

At the Briar Hill Steel Co., Youngstown, Ohio, the new plate mill, which rolls plate exclusively, consists of two mills, one a three-high single-stand 132-in. mill, the

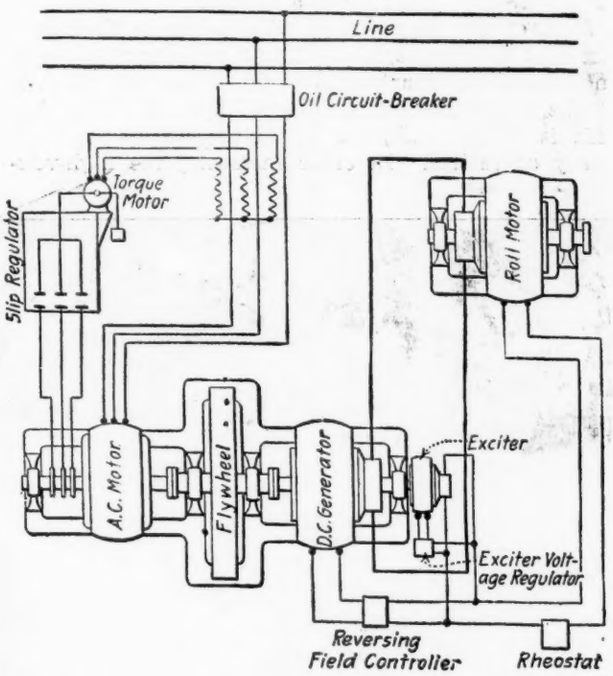


FIG. 9. WIRING DIAGRAM OF THE MOTOR CONTROL

other a two-stand 84-in. mill. The roughing rolls of the 84-in. mill are driven by a reversing direct-current motor having a maximum torque of 1,000,000 ft.-lb. at 40 r.p.m. This motor is supplied with energy from a 1,500-hp. three-phase 60-cycle 2,200-volt induction-motor direct-current generator set. The 2,250-kw. 600-volt direct-current generator is shunt wound and separately excited. It is equipped with commutating poles and compensating windings. On the shaft of this unit is mounted a 60,000-lb. flywheel.

A liquid slip regulator connects with the secondary winding of the alternating-current motor, equalizing the input to the flywheel. Thus, when the motor load reaches a certain fixed volume, the regulator cuts in resistance in the secondary winding, which causes the motor to tend to decrease its speed, and the flywheel gives up some of its energy and so absorbs the short peaks of the roll motor. Just as soon as the peaks go off, the regulator gradually decreases the secondary resistance and the motor speeds up, bringing the flywheel back to full speed again ready for the next peak. Owing to the arrangement of the regulator, the motor cannot be started until the maximum resistance is cut in on the secondary, by means of the slip regulator being wide open. Starting and stopping of the motor is accomplished from a benchboard controller without manual setting of the regulator. The switching of the motor is arranged so that it can be stopped within a few seconds by the application of reverse power.

Motors used for driving mill-roll trains are usually of the mill-type, totally inclosed; but in some instances a single motor drives a layshaft carrying gears which mesh with corresponding gears that carry the mill-rod train. Direct-current mill-type motors are used for many purposes as steel-mill auxiliary drives. Such motors are built in sizes up to and around 275 hp. and are designed to operate under very heavy duty, especially on front and rear mill rolls and screwdowns where the motor is started, stopped and reversed as frequently as a dozen times a minute.

Most of the larger steel mills generate their own electrical energy at high alternating-current voltage, but it must be transformed to direct current before it can be used with a direct-current type of mill motor. This is done by the use of motor-generator sets or rotary converters. In other instances, the high-voltage current is purchased from outside sources and must also be transformed before it can be used. Fig. 10 shows a substation at the main plant of the Youngstown Sheet and Tube Co.

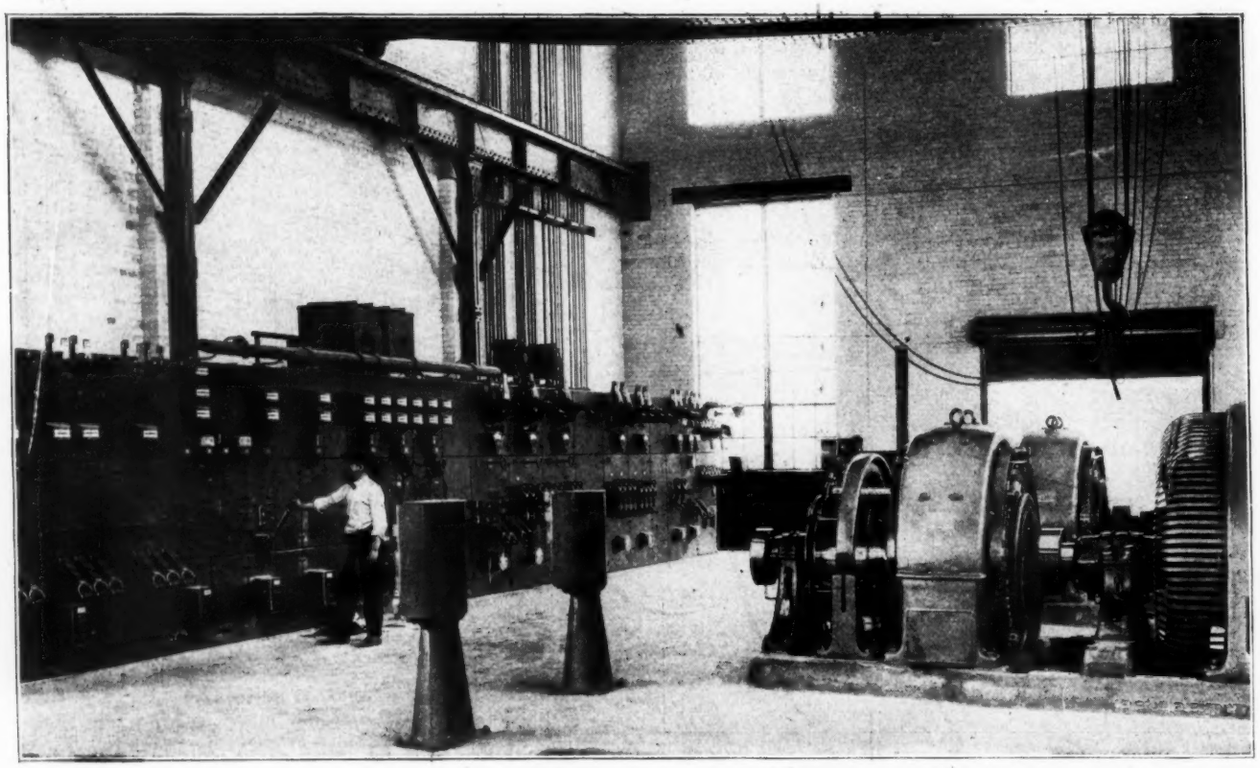


FIG. 10. AN UP-TO-DATE SUBSTATION, SHOWING SWITCH BOARD AT THE LEFT

(*The next article will deal with some of the pumping units used for supplying water for various purposes about steel mills.*)

Ammonia Coils for Cooling Water

BY A. G. SOLOMON

An estimate of the cooling effect of ammonia coils based on ordinary units of heat transmission through pipes is likely to be very misleading because the rate of heat flow from water, brine or air to the ammonia in a coil will vary greatly, depending on the circulation of whichever substance surrounds the coil. This statement is made plain when one considers the insulating effect of still or slowly moving brine or air in close contact with the ammonia evaporating coils.

The lowest rate of heat transfer is found to occur in cold-storage rooms having direct expansion coils hung on the walls. The air surrounding such coils is almost still, as the very slight natural circulation is retarded by the pipes of the coil being placed one above the other. The rate of the heat transfer in such cases will never be more than 1.5 B.t.u. per hr. per sq.ft. of pipe surface for each degree difference in temperature between the ammonia in the coil and the surrounding air.

The highest rate of heat transfer is found in brine coolers of the shell and tube type where the brine is forced through the tubes at a high velocity and where the ammonia space is operated as in the flooded system. Here the heat flow can be as high as 25 or 30 B.t.u. In ice tanks having good brine circulation and the flooded system of ammonia evaporation, the heat flow will be about 10 B.t.u. We will assume that the water is cooled in a tank where the flow amounts to 200 gal. per hour and that water is being admitted and taken out continually as in the ice-plant forecooler.

Under the most favorable operating conditions the rate of heat transfer from this water to the ammonia will be no more than 7 B.t.u. This figure is considered rather high, but it can be reached. Suppose the average temperature of the water is $(80 + 35) \div 2 = 57.5$ deg. F., and the temperature of the ammonia in the coil is zero, and the temperature difference is 57.5 deg. F. As 7 B.t.u. is the rate of heat transfer for each degree temperature difference, $7 \times 57.5 = 402.5$ B.t.u. is the amount of heat passing through each square foot of pipe surface per hour. Two hundred gallons of water is equal to 1,666 lb. This amount

of water to be lowered from 80 to 35 deg. will call for the removal of 45 × 1,666 = 74,970 B.t.u. in an hour. Dividing the number of heat units to be removed by the heat exchanged through one square foot of pipe surface gives 186.26 sq.ft., or 299.5 ft. of 2-in. pipe; and 20 per cent more pipe, or about 60 ft. of 2-in., should be added to take care of heat leakage through insulation and variations in operating conditions.

A New English Gas Engine

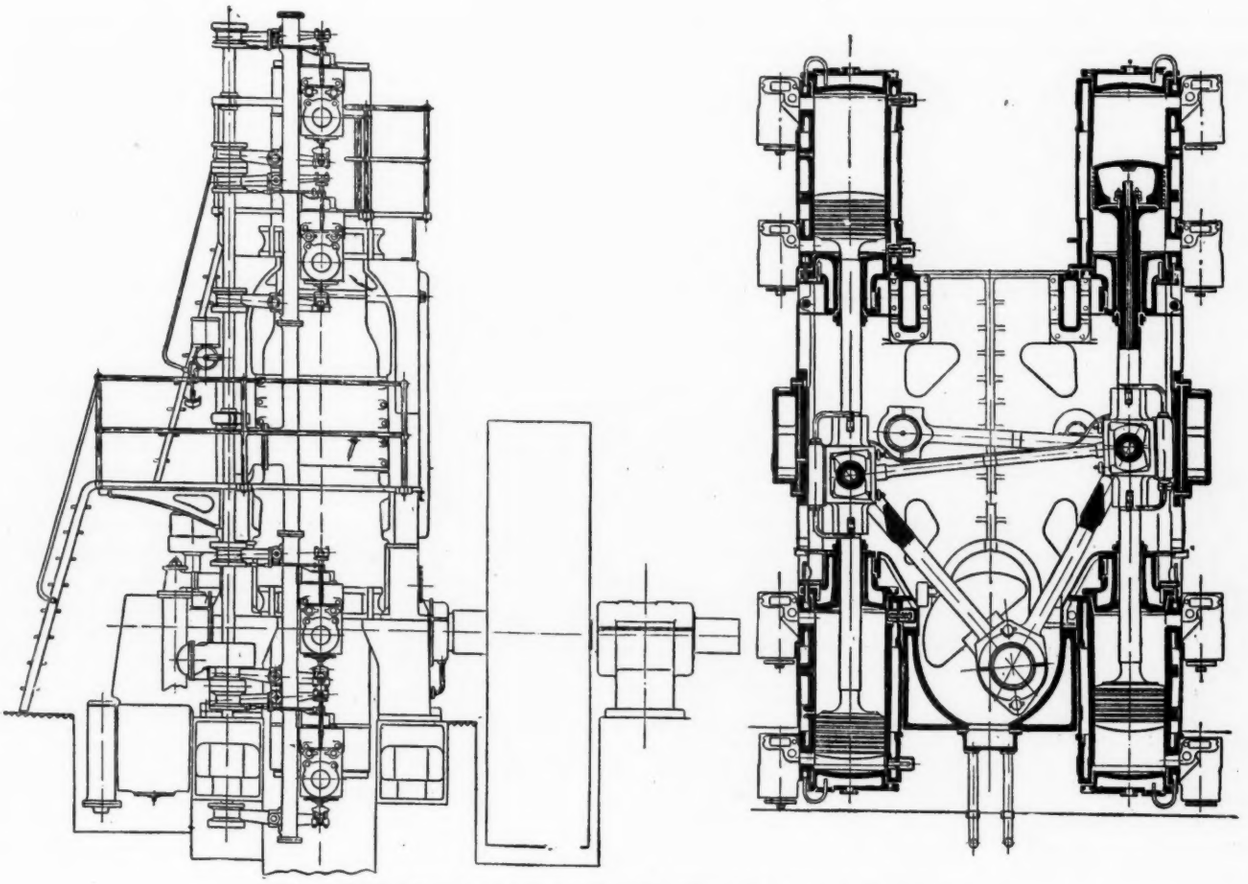
The Premier Gas Engine Works has brought out a large double-tandem double-acting gas engine of a decidedly novel design.

Referring to the sectional line drawing, it will be seen that the cylinders are grouped in pairs, on opposite sides of the crankshaft, with a triangular connecting rod, after the fashion of the old Musgrave steam engine, transmitting the motion of the two sets of piston rods to the single crank. The upper end of the two branches of the connecting rod have gudgeon pins working in short transverse slides in the crossheads, while the right-hand pin also takes the ends of the radius rods that transmit the side thrust of connecting rods to anchor pins on the frame.

The arrangement has the advantage of reducing to a minimum the frictional losses involved in the conversion of the reciprocating motion of the piston to the rotation of the crank. It also gives a very even turning moment. The effect of the triangular rod in this direction is, in fact, equivalent to setting the cylinders at an angle of 60 deg., as in the familiar motor-car engine.

The cylinders of this engine are 24¾ in. in diameter by 30 in. in stroke, which, at a speed of 125 revolutions per minute, gives a piston speed of 625 ft. per min. The mean effective pressure is 66 lb. per sq.in. Working on blast-furnace gas, the engine develops 900 hp., or 1,000 hp. when using producer gas. The over-all dimensions of the engine, including the generator and flywheel, are 18 ft. by 25 ft. by about 20 ft. high above the floor level. A unit of approximately the same capacity, but of the double-acting tandem horizontal type, would require a floor space of 27 x 60 ft. The economy in space is about 70 per cent.

The potential water power of British Columbia experts declare, is equal to that of five Niagaras. Pouring down the mountains comes enough water to develop 3,000,000 hp. At Niagara Falls, there is now developed about 725,000 hp. Only 123,000 electric horsepower is now developed by the plants supplying Vancouver, New Westminster and the towns in that vicinity. This power turns the wheels of mills and factories, propels the street cars of these cities and provides light for the streets and homes. If the entire wealth of British Columbia in water power were harnessed, it would be sufficient to provide power, light and heat for forty cities the size of Vancouver and New Westminster combined. With this cheap power available, economists predict that some day the province will become one of the greatest manufacturing centers of Canada.



SECTIONAL LINE DRAWING OF THE NEW PREMIER GAS ENGINE

What Is the Efficiency of a Steam Engine?

A Discussion of Some of the Misunderstandings Due to Different Meanings Attached to the Names of the Various Steam-Engine Efficiencies

By DeWitt M. Taylor

WHEREVER steam engines are discussed the word efficiency is used, but unfortunately it is frequently used without due care to specify just what it means. To help explain it various qualifying terms are often employed, but authorities differ as to just what certain of these terms mean.

In general the efficiency of a machine or engine may be defined as the ratio of output to input, or of the heat equivalent of the work produced to the heat supplied to the engine. The efficiency of a steam plant, then, might be stated as the ratio of the heat equivalent of the electrical energy delivered at the switchboard to the heat of combustion of the coal burned. This might be and frequently is called the "Over-all Efficiency," although the adjective over-all is frequently used when the heat equivalent of the power at the engine shaft is substituted for the energy at the switchboard. When attempts are made to improve the economy of the engine or plant, it becomes necessary to examine the losses in the various individual parts of the apparatus. This results in the computation of the efficiencies of these individual parts, and it is largely in the names applied to these values that confusion arises.

When dealing with the engine alone, it is usual to consider that the boiler, condenser, piping and auxiliaries operate at 100 per cent efficiency, or, in other words, not to charge the engine with any losses due to imperfections in other apparatus.

In Fig. 1 the essential parts of a steam-power plant are shown and the heat content of the steam at the various significant points is indicated. The steam leaving the boiler has a certain heat content, which may be designated as H_1 or as $q_1 + x_1 r_1$ where q is the heat of the liquid, r is the heat of vaporization and x is the dryness fraction, the subscript 1 referring to the condition of the steam leaving the boiler. Assuming no loss in the steam pipe the steam entering the engine is in the same condition as on leaving the boiler. In passing through the engine some heat is turned into work and some heat is wasted, and the steam leaves the engine with a heat content of $q_2 + x_2 r_2$ where the subscript 2 refers to the condition at exhaust. In the condenser all the steam is condensed, since it does not pay to pump steam back into the boiler. Any additional cooling of the condensate, however, is the fault of the condenser, not of the engine, so the water entering the boiler is assumed to be at the temperature corresponding to the back pressure on the engine. Its heat content, then, is q_2. The heat added in the boiler to each pound of water, therefore, is $q_1 + x_1 r_1 - q_2$, or as sometimes written, $H_1 - q_2$.

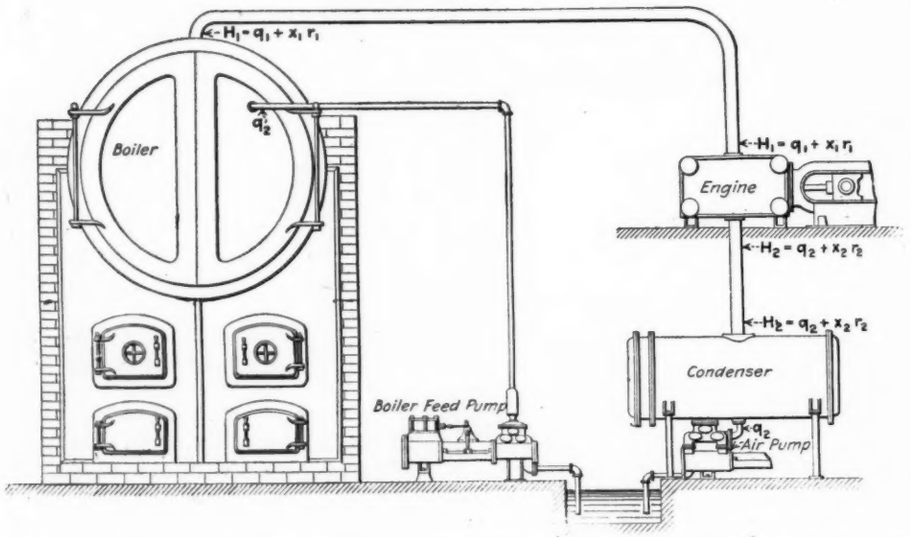


FIG. 1. DIAGRAM SHOWING HEAT CONTENTS OF STEAM AT VARIOUS POINTS AS ASSUMED IN COMPUTING EFFICIENCIES OF ENGINE

The heat supplied in the boiler per horsepower per hour is $W\ (H_1 - q_2)$ where W is the "water rate," or weight of steam per horsepower per hour. The heat turned into work per horsepower per hour is $\frac{33{,}000 \times 60}{778} = 2{,}545$ B.t.u. An efficiency may be figured from this as $\frac{2{,}545}{W\,(H_1 - q_1)}$ and this ratio is often called the "Actual Thermal Efficiency" or sometimes the "Thermal Efficiency of the Actual Engine." It has also been given the name "Thermodynamic Efficiency."

The theoretical cycle known as the Carnot Cycle is sometimes used as a standard of perfection, since a heat engine working on this cycle would have an efficiency that could not be exceeded. The efficiency of an engine working on this cycle is expressed by $\frac{T_1 - T_2}{T_1}$, where T_1 is the absolute temperature of the source of heat and T_2 is the absolute temperature at which the waste heat is rejected. This is usually referred to as the "Carnot Efficiency," but is seldom computed, as the actual steam-power plant operates on a cycle differing materially from the Carnot Cycle.

The usual standard reference cycle for steam plants is known as the Rankine Cycle, and it differs from the

actual cycle only in that the engine proper is made of a perfectly non-conducting material. It can be shown that the heat turned into work by an engine working on the Rankine Cycle is $(q_1 + x_1 r_1) - (q_2 + x_2 r_2)$, where the symbols have the same meanings as in the previous paragraphs with the additional requirement that the entropy during expansion remains constant. Thus the value of x_2 may be computed on the basis of a constant entropy expansion from the condition of steam at the throttle to the pressure of the exhaust. Since the amount of heat added in the boiler is the same whether the steam is expanded in a non-conducting cylinder or in an ordinary engine cylinder, its value

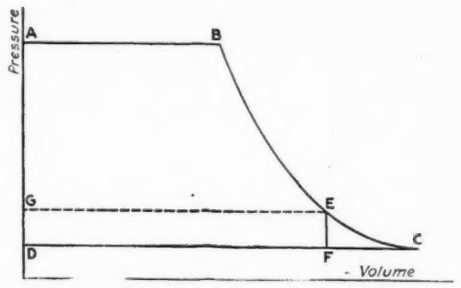


FIG. 2. PRESSURE-VOLUME DIAGRAM FOR RANKINE CYCLES WITH COMPLETE AND WITH INCOMPLETE EXPANSION

per pound of steam is $q_1 + x_1 r_1 - q_2$ or $H_1 - q_2$ as before.

The efficiency of an engine working on the Rankine Cycle, then, is $\frac{(q_1 + x_1 r_1) - (q_2 + x_2 r_2)}{q_1 + x_1 r_1 - q_2}$ or $\frac{H_1 - H_2}{H_1 - q_2}$, remembering that the condition designated by the subscript 2 is found from a constant entropy expansion. This efficiency is usually called the "Rankine Efficiency."

One source of misunderstanding is due to the use of the name Rankine Cycle to refer to two different cycles. The distinction may be understood by referring to Fig. 2, which is a pressure-volume diagram. One cycle is represented by the line *ABCDA*, the curve *BC* representing expansion in a non-conducting cylinder. This is the cycle described before in this article and called the Rankine Cycle. By some writers it has been given the name Clausius Cycle and by others "Rankine Cycle with Complete Expansion."

The other cycle is shown by the lines *ABEFDA* and differs only from *ABCDA* in that the adiabatic expansion is stopped at *E* and the constant volume pressure drop to *F* takes place. This corresponds to the action of a steam engine when the exhaust valve opens before the pressure has dropped to the back pressure. The cycle here described has been called the Rankine Cycle by many people, although some authorities avoid confusion by naming it the "Modified Rankine Cycle" or the "Rankine Cycle with Incomplete Expansion." In connection with the diagram in Fig. 2, it should be remembered that this represents the pressure-volume changes of a definite quantity of steam and is not an indicator diagram.

In computing the work done by an engine operating on the "Modified Rankine Cycle," the portion *ABEGA* is treated as a Rankine Cycle with complete expansion and the work of the portion *GEFDG* is found by multiplying the pressure drop from *E* to *F* (in pounds per square foot) by the volume at *E*. This latter value is reduced to the equivalent heat units and then added to the heat equivalent of the portion *ABEGA* to find the total heat converted into work.

Since a perfectly non-conducting engine can never be built, its water rate cannot be determined by actual test. The heat turned into work per pound of steam however, as stated before, is $(q_1 + x_1 r_1) - (q_2 + x_2 r_2)$ or $H_1 - H_2$. The heat that must be turned into work to deliver one horsepower per hour is 2,545 B.t.u., therefore the water rate for an engine working on the Rankine Cycle would be $\frac{2{,}545}{H_1 - H_2}$, and this value is often called the "Rankine Water Rate."

When two engines receive steam at the same pressure and quality and exhaust at the same pressure, either their actual thermal efficiencies or their actual water rates serve as a fair basis on which to compare their performances. When, however, the condition of the steam supplied or the exhaust pressures are different, it is not fair to compare two engines on this basis. For example, assume one engine receiving dry steam at 250 lb. absolute and exhausting at 28 in. vacuum, and a second taking dry steam at 50 lb. absolute and exhausting at atmospheric pressure. In the first case the Rankine Efficiency would be 30.8 per cent, while in the second case it would be 27.2 per cent. If, then, the two engines were found to have the same thermal efficiency, the latter would be the better engine, since it comes nearer its ideal standard. In other words, the Rankine efficiency represents the ideal efficiency for the conditions under which the engine operates and over which the engine has no control, and the best engine is that one which makes the most of its opportunities.

For this reason it is customary to compute the ratio of the actual thermal efficiency to the Rankine Efficiency for the existing conditions. It is in connection with the names given this ratio that the most confusion arises. Some authorities call this the "Cylinder Efficiency," but this has been objected to when applied to steam turbines. The term "Cycle Efficiency" has been used, but as this is sometimes applied to both what we have here called the Rankine Efficiency and the Thermal Efficiency, it causes confusion. The term "Rankine Efficiency" has also been applied to this value, but this is very confusing, since so many use this name as it has been used in this article. Other names have been used, but so far as the writer knows, the term Cylinder Efficiency is the only one that is not also used with another meaning. While this term apparently means nothing when applied to turbines, it at least has only one meaning in general use.

Differences in what is to be considered as the output of the engine also lead to confusion. When reciprocating engines only were considered, the output when figuring thermal efficiencies was taken as the indicated horsepower. This was the logical procedure, since efficiencies based on brake horsepower included the mechanical losses in the engine. With the advent of the turbine, however, and the difficulty of determining a value corresponding to the indicated power of a reciprocating engine, efficiencies were often computed on the basis of the brake horsepower. When the efficiency of an engine based on indicated horsepower is compared with that of a turbine or another engine based on brake horsepower, the results are likely to be misleading.

Since uniformity of nomenclature is obviously desirable, the following definitions are suggested:

Carnot Efficiency is the efficiency of a theoretically perfect engine working on the Carnot Cycle and is given by the expression $\frac{T_1 - T_2}{T_1}$.

Rankine Efficiency is the efficiency of an engine working on the Rankine Cycle and is given by the expression $\frac{H_1 - H_2}{H_1 - q_2}$.

Thermal Efficiency is the ratio of the heat equivalent of one horsepower-hour to the heat supplied to the engine for each horsepower-hour and is given by the expression $\frac{2{,}545}{W(H_1 - q_2)}$. Unless otherwise stated, this value is based on the indicated horsepower.

Cylinder Efficiency is the ratio of the Thermal Efficiency to the Rankine Efficiency.

Mechanical Efficiency is the ratio of the brake horsepower to the indicated horsepower.

The symbols used in the foregoing definitions are those explained earlier in this article. To make these statements cover all cases, the symbol H may be taken to mean the heat contents of wet, dry or superheated steam.

It is realized that some of these definitions at least are likely to incur criticism, but they are offered as suggestions in the hope that this or some other list of definitions may become standard. Probably such a standard can become widely recognized only if it is backed by some such body as the American Society of Mechanical Engineers.

Testing a Closed Heater

BY R. W. RIORDAN

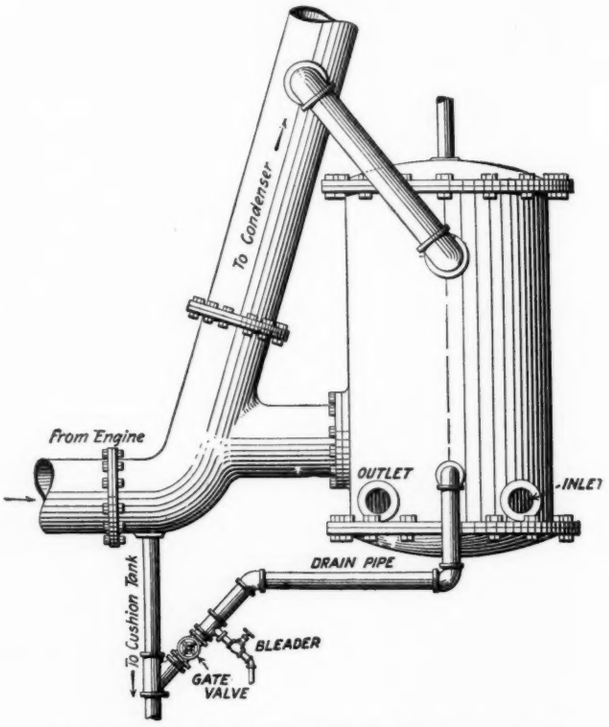
A closed heater, set vertically, was connected to the exhaust pipe of a 2,700-kw. cross-compound unit, about midway between the cylinder and a barometric condenser, as shown in the sketch. The lower connection was of the same diameter as the exhaust pipe; the upper one was much smaller, but of sufficient capacity to allow circulation of the exhaust steam. A drain pipe leading to a "cushion" tank carried off any condensate accumulating on the bottom tube sheet, and on this drain line a bleeder valve was placed to determine whether there was any excessive flow of water passing through this line, indicating a leak in the heater. After a run of any appreciable length the heater was tested as soon as the unit was shut down.

Water from the city mains flowed through the tubes, which were divided into sections, providing for six passes, and the temperature rise obtained varied from 50 to 75 deg. before going to an open feed-water heater. The city water averaged 50 lb. gage, and with a pressure of 2 lb. absolute on the steam side of the heater considerable water was wasted when leaks occurred in the tubes, for the condensate and circulating water were discharged from the "cushion" tank into the canal running alongside the plant.

The point that I wish to bring out is the difficulty experienced in locating the leaking heater tubes and how this difficulty was overcome. Of course, on account of the layout of the piping, it was out of the question, when testing to locate the leaks, to fill the steam side of this heater with water, as is often done with those of horizontal design, so the candle test was applied, while a vacuum was maintained in the steam space. This method proved unsatisfactory, for while it located one serious leak, it failed to disclose the whereabouts of several minor ones, and the result was that the total leakage was reduced only about one-half.

Next, the bottom head was put back in place and the tubes were filled with water to a height of a few inches above the top tube sheet. The vacuum pulled the water level down in two certain sections, indicating leaks in those sections, but that was all. The suggestion of putting steam pressure on the exhaust side of the heater was next carried out, but naturally, the water absorbed all the steam that leaked through, and when the tubes were drained dry the heat evidently expanded the metal and closed up the leaks.

After much discussion among those of the operating force, the use of compressed air was suggested, and this



PIPING OF CLOSED HEATER TO EXHAUST PIPE

method gave the most gratifying results. A hose was used to connect the compressed-air reservoir with the small bleeder valve on the drain line of the heater, and with the water a few inches above the top tube sheet, the air was turned on. On account of the small capacity of the hose and the bleeder valve, it was impossible to create a pressure of air in the exhaust-steam space as had been planned, for the air leaked through stuffing boxes, valves, etc., as fast as it flowed to the heater. After waiting a sufficient length of time to allow all the passages to become filled with air, the throttle valve of the engine was opened slightly. This produced the desired result, for the steam rushing through the engine and exhaust pipe, drove the air before it and caused such a rapid rise of pressure in the heater that air was forced through the leaks in the tubes. It was then a simple matter to mark the tubes from which the air bubbles were discharging. Several leaks were located and repaired, and when the heater was closed up and tested, not even a trickle of water appeared at the bleeder.

Operation and Adjustment of Turbine Machinery-III Examining Turbines and Generators

By EUSTIS H. THOMPSON
Consulting Engineer, Baltimore, Maryland

WHEN a large-sized turbine is put into operation, the same course as for small turbines is pursued but with greater refinement. The piping and foundations should be carefully gone over. Strains due to pipe weight should be eliminated. In large machines an expansion joint is always placed at the condenser.

After cleaning and filling with oil comes the question of mechanical adjustment. In large machines alignment becomes the greatest single factor, as it affects the operation of the steam upon the blades, and the shaft packing rings as well as the operation of the bearings, couplings and the whole machine itself. Alignment depends upon the accuracy with which the machine is installed, and this should be among the first things checked. Alignment of bearings does not need to be checked in a two-bearing unit. In a three-bearing set this is checked by separating the coupling flanges a small amount and then measuring between them with a feeler gage to see that they are approximately parallel. The flanges should separate equally on each side, but the top should open up somewhat more than the bottom, which is usually from 0.002 to 0.006 in. to allow for expansion in the turbine end. In a turbine and generator set that is mounted on four bearings, the coupling is usually set so as to be parallel at the flanges and also central in regard to the axis of each shaft. The flanges can be measured as before to check them for parallelism. They can be tested for eccentricity with a straight-edge. Lay the straight-edge on one flange parallel to the shaft and allow it to project so as to touch the other flange. This should just barely touch on both sides, top and bottom. It is customary, if the machine is cold, to set the generator a little higher than the turbine so as to allow for turbine expansion. This allowance is 0.004 to 0.008 in. per foot of height above the bedplate.

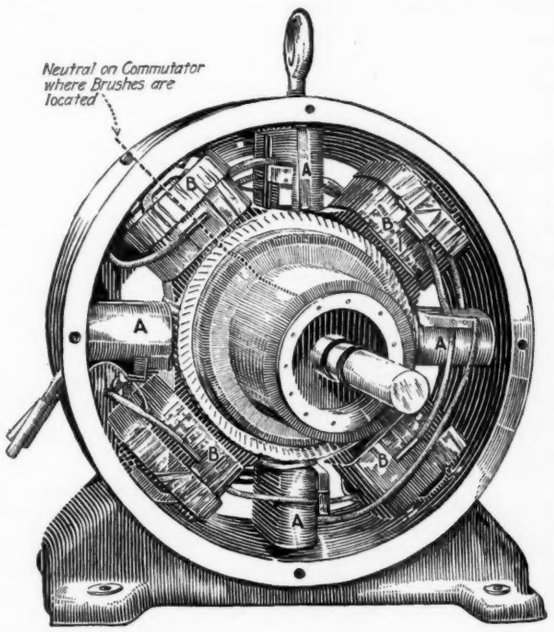


FIG. 1. THE MECHANICAL NEUTRAL POINT IS THE COMMUTATOR BAR THAT CONNECTS TO THE COIL IN THE CENTER OF THE SPACE BETWEEN THE MAIN POLES

The alignment of the shaft and turbine casing should be checked by removing the cover of the packing rings at each end of the machine and measuring from the shaft to the bored surface of the casing. The casing should be central under full-load conditions when it has reached its running temperature. In checking this alignment when cold, expansion should be considered. It often happens that the turbine bearings are supported directly on the turbine casing. Then there is little expansion effect. When the bearing is supported on the bedplate, we have greatest expansion of the turbine casing. The allowance for expansion should range from 0.002 to 0.01 in. per foot of height.

Impulse turbines do not require as close an alignment in this respect as reaction turbines, generally speaking, as in the former case there is only the nozzle alignment to be considered, while in the latter there is often a close clearance between revolving blades and turbine casing.

Setting the clearances is the next principal adjustment. This refers to axial clearance or, in other words, the distance measured parallel with the shaft from a moving blade to a stationary blade taken on each side. Before moving the shaft so as to adjust this clearance, be sure to look the rotating element over from end to end so that there will be no danger of damaging an oil deflector, gear or piece of governor mechanism. All such parts should be either disconnected or held under close observation. Peep-holes are usually provided by which it is possible to measure the actual clearances with a shim gage. The shaft can then be set so that the revolving and stationary blades will properly clear, with an allowance for expansion. It should be borne in mind that the shaft expands away from the thrust bearing. The revolving blade, therefore, should be set fairly close to the stationary blade —that is, on the same side as the thrust bearing—and the excess clearance can then be taken up by expansion away from the thrust bearing.

Some thrust bearings are set by means of shims. These shims can be removed until the shaft is moved into its proper position, and then they can be replaced in accordance with the new setting of the bearing. The shaft can be moved endwise by using a bar or a small jack against some solid part of the rotor. Thrust bearings are often made with a bolt which can be turned to move the shaft. It is safer, in this case, to turn the machine over by hand or by light steam pressure when moving the thrust bearing.

In turning over a large machine it is often most convenient to take a few turns round a coupling flange with a rope and pull one end with a crane.

There is another method of setting the clearances

when it is not convenient to measure them through peep-holes. This consists in turning the machine over and setting the shaft toward one end until rubbing is heard and then setting the shaft in the other directon until it rubs at the other end of the travel. The actual travel of the shaft can be measured and the final setting made in the middle of this travel. This is best suited to small, rigid machines, but should be undertaken only with the greatest care and preferably omitted, if possible, in large machines with delicate blading.

The radial clearance, or that which is measured from the revolving blades to the turbine casing in a radial direction, is usually so large as to be negligible in impulse machines, but is of great importance in reaction machines. This adjustment is made in lining up the turbine casing and simply means, in the latter case, that the job should be well done.

Further progress follows the course of that pursued in smaller machines. Often an auxiliary oil pump driven by steam is supplied for use in starting. Sometimes the oil rings are omitted and it is necessary to use a squirt can on each bearing before starting. Bearing temperatures should be watched with greatest care; also leakage of oil along the shaft that might work its way into the generator should bear close scrutiny.

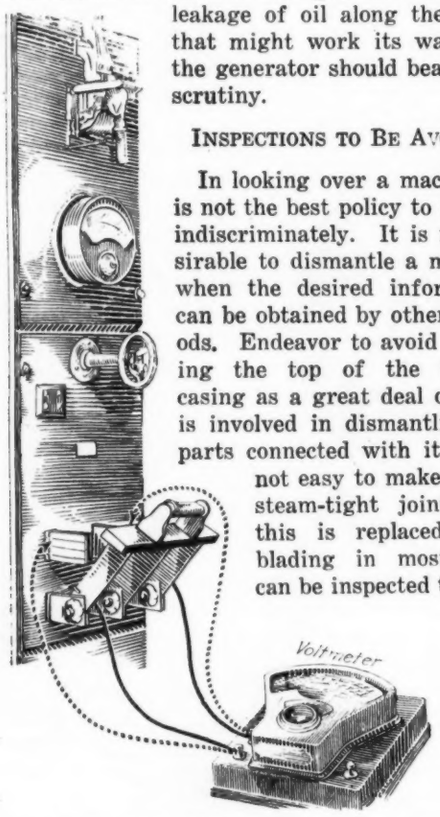


FIG. 2. TO TEST THE POLARITY OF THE MACHINE A POSITIVE VOLTMETER IS CONNECTED ACROSS THE OPEN MAIN SWITCH

Inspections to Be Avoided

In looking over a machine it is not the best policy to inspect indiscriminately. It is not desirable to dismantle a machine when the desired information can be obtained by other methods. Endeavor to avoid removing the top of the turbine casing as a great deal of work is involved in dismantling the parts connected with it. It is not easy to make a good steam-tight joint when this is replaced. The blading in most cases can be inspected through peep-holes. In special cases, where there is reason to suspect trouble with the buckets, it may be necessary to dismantle the machine. The packing rings should always be tested by actual operation rather than by inspection. Assembling the packing is sometimes the most difficult job on the whole machine, and there is always a chance of breaking the delicate and expensive packing rings. The governor itself is difficult to assemble and should not be taken apart unless there is good reason and plenty of time for the work.

Steam engineers frequently are required to handle electric generators. In small plants especially, the engineer is frequently required to take charge of everything from supplying coal to the boiler up to the point of delivering mechanical energy from the electric motor. Putting a generator in service may become the engineer's responsibility, and this may prove an easy job or an unlooked-for accident may make it appear to be a proposition of no small proportions.

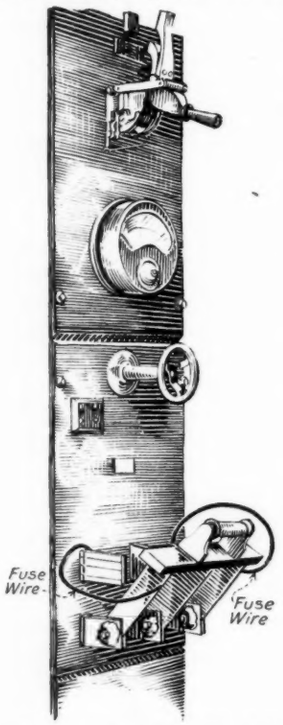


FIG. 3. JAWS AND BLADES OF MAIN SWITCH CONNECTED WITH FUSE WIRE WHEN POLARIZING MACHINE

Placing an alternating-current generator in service is comparatively simple. The brushes on the collector rings should be accurately fitted and the machine blown out and wiped off as before. When using compressed air, always use a fairly light current of air which would be equivalent to a strong electric fan close to the blades. Very high air pressure is injurious to the insulation and causes varnish, mica and wrapping to be blown off eventually.

An alternator is thrown in on the line by means of a synchronoscope. There are many methods of connecting synchronoscopes and of testing them to make sure they are right before throwing in a machine. The simplest method for checking them is, in the writer's opinion, as follows:

First, test for phase rotation. Bring the voltage up to normal; clear all the other generators off the switchboard and close the switch of the new generator so that it will energize the busbars.

Then start one of the induction motors on the line or in the power house. If this machine rotates in its usual direction, the phase rotation is correct. If not, the phase rotation must be corrected by interchanging any two of the three leads of a three-phase generator and either phase leads of a two-phase machine.

After the phase rotation has been corrected, the synchronoscope should be checked for accuracy. Disconnect the cables coming from the machine at the generator itself and mark them so that they can be connected again in the proper manner. Insulate the cables from the oil switch. Now close the oil switch, which will energize these leads with current from the busbars. Plug in the synchronoscope, and if the connections are correct it will read 12 o'clock. If it jumps to any other position, the connections should be corrected. In case the instrument is already in the 12 o'clock position, it should be moved away by hand so that its action can be plainly noted when it is plugged in. After opening the oil switch, the machine can now be connected to the leads and brought up to speed and loaded.

Direct-current generators are directly connected to turbines only in small sizes, and in larger sizes are connected through reduction gears. They should be dis-

connected until the turbine has been put in good running condition. It is a good plan to open the field circuit by disconnecting at a terminal so that there will be no danger of the voltage building up unexpectedly, until the engineer is ready.

The air gap between the rotating and stationary parts should be checked in all positions. The brushes should be sandpapered so they will fit the commutator. This is a delicate matter on high-speed machines. A good surface that fits the commutator can be secured by sandpapering against rotation with rough sandpaper and then going over with fine sandpaper, this time in the same direction of rotation.

The dust should be blown out with compressed air or, if none is available, a hand bellows may be substituted. Keep the current of air away from the windings so that the dust will be blown away from the machine. Wipe the brushes off with a clean rag and place them in the brush-holders. The remaining parts of the brush rigging and insulators, cable connections, etc., should be carefully wiped.

The brushes should be set in the running position. In many cases the brush rigging is marked with a pointer or other means so that this position can be easily located. In nearly all cases the running position is at the mechanical neutral point or perhaps one or two bars with rotation from this point. The foregoing applies to interpole machines, and in generators without interpoles the running position is sometimes two to four bars off the neutral. Machines of this character are not built to any great extent for turbine work. The mechanical neutral point is the commutator bar that connects to the coil in the center of the space between the main poles. This can most easily be found by marking the armature end windings between the main poles and then following the lead nearest this mark down to its commutator bar. In an interpole machine the neutral is at the center of the interpoles *A*, as indicated in Fig. 1.

If the coils lead off toward the center of the main poles *B*, then the neutral point on the commutator will be opposite the center of the main poles, and it is in this position that the brushes must be located.

Connect up the field. Test the machine for grounds with a magneto, turn the rheostat so that the resistance is all in and bring the machine up to speed. Build up the voltage slowly by turning back the rheostat and short-circuiting the field resistance. Watch the commutator as the voltage rises.

Testing Machines for Polarity

The next step is to test the polarity of the machine and of the equalizer before closing in the main switch. This can be most easily done by closing the circuit breaker and placing the leads of a voltmeter across the blades of the main switch and also across the jaws of the switch, as in Fig. 2. The voltmeter should be of the positive type, which will read backward or deflect back of zero when current is circulating through it in the wrong direction. The meter reading from the left blade to the right blade should be the same as that from the left jaw to the right jaw. If the voltmeter reads right in one of these positions and reads backward in the next, it indicates that the polarity of the machine is reversed.

The easiest way to polarize the generator correctly with absolute safety is to shut down and remove the brushes. The brushes should be placed so that they will not touch the commutator or the frame of the machine. It is general practice to let the brushes on the lower studs hang by their pigtails while the brushes in the upper studs can be thrown backward over the studs so that the pigtail will not allow them to touch the commutator. Also it is a little more trouble but somewhat safer to place these brushes crosswise on the tops of the holders and hold them in place with the spring. If some fiber is handy, this can be slipped between the brushes and the commutator instead of removing brushes from the holders.

Now turn the rheostat to the "all-in," or "low-voltage" position. See that the circuit breaker is open. Connect the left switch jaw to its blade with a piece of fuse wire. Do the same to the right switch blade and jaw, as in Fig. 3. Now close the circuit breaker and slowly cut out the resistance. Then cut the resistance all in again so that the field current will be reduced as much as possible and open the circuit-breaker and remove the fuse wire.

Field May Be Wrongly Connected

Bring the voltage up to normal as before. Now test for polarity, and if the directions have been followed it cannot fail to be correct, except in the possible case of the field being wrongly connected. When the field is wrongly connected, the voltage will not build up. The remedy is to reverse the field connections at the machine. In case there should be an open-field connection, there will be no arc when the circuit breaker is opened as before described.

Take the polarity from one switch blade to the equalizer switch blade and then to the two corresponding switch jaws. If the equalizer is on the proper side of the line, the same polarity will be obtained in each case. The machine can now be adjusted to the same voltage as that on the switchboard and closed in on the line and loaded.

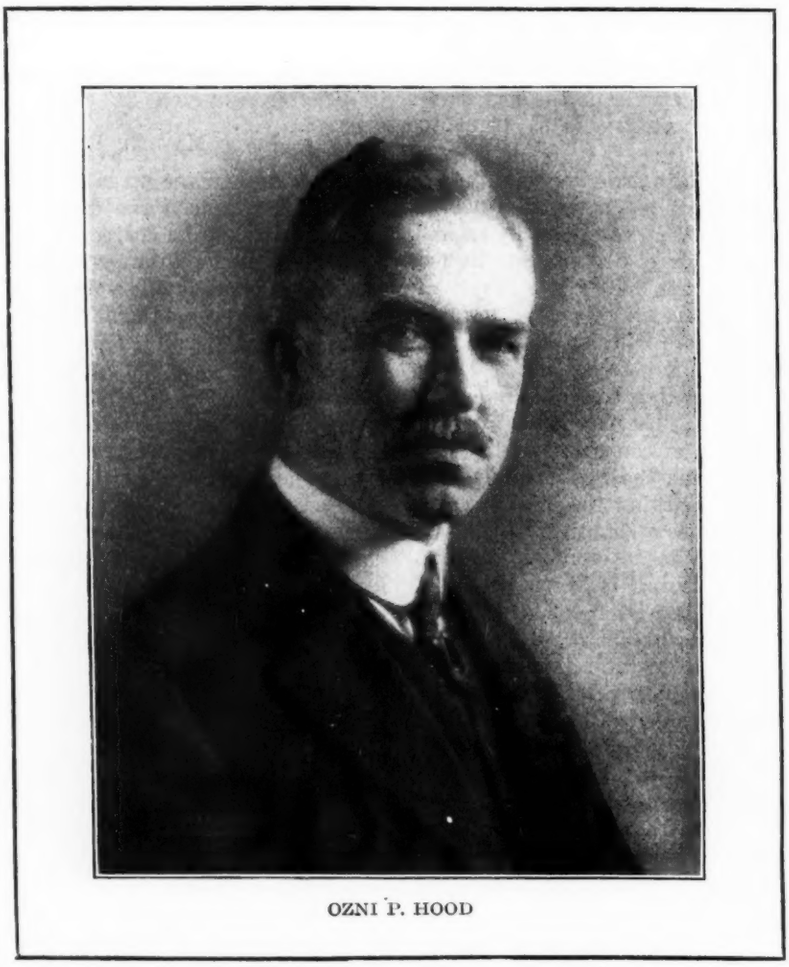
(In the next article Mr. Thompson will explain some points on the proper handling of a turbine.)

Experience has shown that wire ropes of compound construction, subjected to corrosion influences, are likely to deceive engineers as to the strength remaining in them, says a circular issued to managers of mines on the Rand, South Africa. Where reduction of diameter or circumference of the rope has taken place, not accounted for by the evidence of wear, the part of the rope under examination should first be fully loaded and then relieved of the load. Any noticeable difference in circumference in these circumstances and the slackening of the outside wires when the load is off will indicate that internal corrosion has taken place. The extent of corrosion inside the strand can be estimated only by the slackness of the outside wires. The corrosion between the strands can be further examined by untwisting the rope or displaying the strands sufficiently with a marlin spike.—*The Engineer.*

An ideal air compressor would have no clearance space at the end of the compression stroke or cycle, as any air remaining in the clearance space simply expands again, reducing the capacity of the unit. As zero clearance is practically impossible as well as inexpedient, and cooling in the compression chamber limited, when high pressures are desired it is found advantageous to use multiple-stage units, cooling the air between the stages in what are known as intercoolers.

Ozni P. Hood, Chief Mechanical Engineer of the Bureau of Mines

DURING the war the national peril aroused an acute public sense of the importance of fuel economy. By the suggestion of simple measures, and a ready acceptance of them by fuel users through patriotism or apprehension of a compulsory shut-down, it was demonstrated positively that fully a quarter of the nation's coal consumption can be saved, and this by ordinary attention to common principles and simple practices. As a war measure this work of the Fuel Administration was a success. It would be equally beneficial, if not so imperative as a peace measure. The hope has been that it would be carried on by the Bureau of Mines, and the possibility of making a start in this direction by having the Bureau undertake the inspection of coal on its way to the purchaser has been discussed. Should this be done, the man who would probably be intrusted with the institution of the system is Ozni P. Hood, the Chief Mechanical Engineer of the Bureau. Just at the present time Mr. Hood's attention is being directed toward the solving of the mechanical and chemical obstacles which separate the great lignitic resources of the country from commerical success. A plant embodying many ideas worked out in Mr. Hood's office is being created in the North Dakota lignite field, and the most pretentious effort ever made to commercialize lignite is well under way.



OZNI P. HOOD

Practically every year of Mr. Hood's life, since the days he worked as an apprentice for his father, who was a pioneer in the development of cash registers and adding machines, has seen an accomplishment of more than ordinary merit. Much of his work has been with the idea of increasing the efficiency of power plants.

Mr. Hood was born in Lowell, Mass., June 14, 1865. His parents moved to Indianapolis shortly after his birth, and it was there that he learned his trade as a pattern and model maker and secured his early education. His technical education was obtained at Worcester Polytechnic Institute and at Rose Polytechnic Institute. He was among the first to be graduated by the latter institution. His first position after graduation was as instructor and mechanical engineer at the Kansas State Agricultural College. He was a member of the faculty of that institution for twelve years. He then joined the faculty of the Michigan School of Mines, where he served thirteen years. In addition to his school work Mr. Hood was allowed to maintain a consulting practice. During the thirteen years he was with the Michigan School of Mines, he made special reports for nearly every mining company in the Michigan copper district. In 1911 Dr. Joseph A. Holmes came to him with a request that he help him make a success of the Bureau of Mines, which had only recently been established. He accepted the offer and has been Chief Mechanical Engineer of the Bureau ever since. The United States Geological Survey superpower investigation staff is being organized and Mr. Hood has been designated as one of the engineering staff to co-operate in this work. In this work his attention will probably be directed to the various problems of fuel economy.

It is anticipated that gas may possibly form one important medium for the transfer of energy from the western Pennsylvania and West Virginia fields to the region nearer seaboard, where the demands for power and other forms of energy are greatest. If so, it will be very important, indeed, to have these aspects of the work properly represented on the senior board of engineers. Extensive plans have often been discussed for coking of coal at the mine, and it is possible that such engineering projects may require considerable attention in the course of this work.

EDITORIALS

The Emmet Mercury-Vapor Power Apparatus

EVER since Carnot showed that the efficiency of a heat engine depends on the range of temperature over which it operates, engineers and scientists have been trying to increase the temperature range of power-generating apparatus. In the earlier engines steam was used because of its convenience, and the same reasons still exist for its continued use. The difficulties of mechanical construction to handle large pressure ranges, however, placed a practical limit on the temperature range. With this fact in mind, scientists investigated the properties of other substances in the hope of finding a substitute for water vapor, but found the same difficulty in every case. It is true, they found vapors having much higher boiling points at usable pressures, but these same vapors had high boiling points at workable condenser pressures so that no very great gain was made in the available temperature range. The same facts held for substances having boiling points lower than that of water.

The next suggestion was to use two substances in series. A liquid having a high boiling point was to be vaporized in a boiler, used in an engine or turbine and condensed in a condenser which acted as a boiler for a second liquid having a lower boiling point. This second substance was to be used in an engine and condensed as usual. In most cases water was suggested as one of the substances—sometimes as the first and sometimes as the second, depending upon the properties of the other liquid chosen.

On paper this scheme worked beautifully. It promised to revolutionize the power-plant industry. Its actual application, however, encountered obstacles. The complicated apparatus necessary offered apparently unsolvable problems. The chemical properties of the various substances presented new difficulties. Thus, most engineers came to think that the binary-vapor power plant was a good idea that could not be made to work.

One man, however, felt that it could be made to work. He knew that the idea was theoretically sound and was convinced that the practical difficulties could be overcome. In this issue of *Power* is a short account of the binary-vapor apparatus using mercury vapor and steam which has been developed by W. L. R. Emmet. Mr. Emmet made public a description of his plant about six years ago, and at that time he apparently had a workable apparatus. The intervening time has been spent in experimenting and perfecting the various details until commercial application seems possible.

When the Edison Medal was presented to Mr. Emmet recently, he stated, in reply to remarks by H. W. Buck, that commercial application was being made, and expressed the hope that it would be a commercial success in a very short time. In this connection there is a persistent rumor that an Emmet mercury-vapor plant is being built for the Hartford (Conn.) Electric Light Company. The reputation of President Samuel G. Dunham, of the Hartford company, for intelligent progressiveness in power-plant engineering, adds strength to this rumor. It will be remembered that it was in the plant of this company that the first steam turbine of commercial size was installed for electric-power generation. It would be appropriate if the first commercial binary-vapor plant should be installed there.

The success of Mr. Emmet's apparatus will have an almost revolutionary effect on power-plant engineering. It cuts down, by a very appreciable amount, the loss of available heat, which results from the big temperature drop from the furnace to the water in the ordinary boiler. In other words, it increases the amount of heat that may be transformed into power and decreases the amount that must be thrown away in the condenser cooling water. Thus, the power per unit of fuel in the central station will be greater. In the industrial plant using exhaust steam for heating or steam at any pressure for processes, power may be taken out from that part of the temperature range which has been unavailable. The date of the installation of the first commercial Emmet mercury-vapor plant will take a prominent place among the epoch-marking dates in engineering history.

The Interstate Inspection of Boilers

C. O. MYERS, chief deputy in charge of the boiler-inspection division of the Industrial Commission of Ohio, has an article in the July issue of the *International Steam Engineer* which deserves wider circulation and the interested attention of all who are concerned with the inspection of boilers. With the boilers already installed a state department can deal after its own fashion without complications with the boiler manufacturers or the inspection departments of other states. In any effective system of supervision, however, new boilers must conform to some accepted standard, and unless there is to be all sorts of confusion in the interstate use of boilers and all kinds of expense and complication to manufacturers, there must be a common standard, a boiler built to which will be acceptable to the inspection department of any state.

Such a standard is that formulated by the Boiler Code Committee of the American Society of Mechanical Engineers. A boiler built to that code, the adequacy of which has been avouched by the best authorities on boiler construction in the world, ought to be acceptable to any board whose decisions were controlled by nothing but real purpose to guard the public safety. But how is the boiler inspection department of Massachusetts, for example, to know that a boiler built in Ohio has been built in accordance with the code? The boiler must be inspected in the process of manufacture, and no state can maintain an inspector of its own in every boiler shop that is likely to send boilers to it.

The natural suggestion would be that the states accept the certificates of each other's inspectors; that

when a duly qualified inspector puts the A. S. M. E. stamp upon a boiler, it should be generally acceptable. But what is a "duly qualified" inspector? Some of the states are more particular than others as to the qualifications of the men upon whose painstaking and conscientious performance of their duty, life and property depend. It is not unheard of that a barber or another having as little training for and knowledge of the boiler inspector's duties has been appointed through political favor to this office, and it is the possibility of such malpractice that makes it impracticable to get the heads of all state departments to agree unreservedly to accept each other's inspections.

A logical solution is through the national organization of the heads of inspection departments, known as the National Board of Boiler and Pressure Vessel Inspectors, of which Mr. Myers is secretary. This organization ought to determine what the qualifications of an inspector should be, and every inspector should be required to pass its examination and receive its certificate of competency. Most of the chief inspectors of whom the board is composed control the appointment of the inspectors under them, and in a case where one does not, the appointing power would hesitate to appoint a man who could and would not qualify under such an arrangement. If this could be done, the department of any state could accept with confidence a boiler marked with the A. S. M. E. stamp, confident that it has been put there by one competent to certify that it has been built in accordance with the requirements of the code.

What Is the Efficiency of a Steam Engine?

A RECENT number of a popular magazine contained an article on the question of what is a luxury? It was pointed out that a luxury is something we can do without, while a necessity is something we must have if we are to live in decency, comfort and health. That was easy to define, but when it came to making legal lists of luxuries and necessities trouble began. There were too many differences of opinion.

In the same way the word efficiency seems easy to define, but when we try to pin it down to actual application in engineering, there are differences of opinion and more or less confusion. It is one of the prime requisites of an engineering vocabulary that no ambiguity or uncertainty of meaning is permissible. Therefore it is to be regretted that a word so frequently used as "efficiency" should be used in so many different senses. Someone has said that it is a word that should never be used without a qualifying adjective. In engineering literature it generally is accompanied by an adjective, but different men attach different meanings to the same adjective and the confusion is only made worse.

Power frequently receives letters calling attention to supposed inaccuracies in articles when the only error consists in a difference in the meaning attached to the same term by the author of an article and the correspondent who criticizes it. Both are correct according to their own interpretations of the terms, and both have authority for their interpretations. The result is confusion and unnecessary controversy over points on which everybody is really in accord.

This confusion of terms is an especial hardship on the student or recent graduate of a technical school. The faculty of his school use a given set of names for the various efficiencies, and the student learns to think in those terms. When he attempts to read general engineering books or papers or comes in contact with engineers from other schools, he finds what seems to him a foreign language. His time must be spent learning over again what he has already been taught instead of acquiring additional information.

In this issue of *Power* is an article which points out a few, but only a few, of the cases where authorities differ in the names of the various ratios which come under the broad head of efficiencies. This article contains a short list of suggested definitions as the beginning of a standard for these terms. Obviously, action by some representative body of engineers is necessary before any general adoption of such definitions, but it would appear that some such action should be taken or at least considered.

Cheap Hydrogen?

TWO more inventors have wandered off into that path that leads to a dead end. Two Grand Rapids boys, now serving sentences in the state prison at Marquette, have written friends at home that they believe they are successful in developing a chemical process from which they may devise means of commercially extracting hydrogen from water, thus affording fuel and power startling in economy.

It takes as much energy to separate hydrogen and oxygen as they will generate by coming together again. The alleged discovery is just the same as though they had discovered a new way of lifting a weight. However it is lifted, it will take as much energy to separate its center of gravity from that of the earth as will be generated by their approach to the original distance. In combustion the atoms of hydrogen and oxygen "fall" toward one another, and the momentum acquired in the fall is heat. It takes as much energy to "lift" them away from one another as is generated by their rush toward one another. There is nothing in it unless the dissociation can be effected by energy now wasted.

According to the fourth monthly bulletin on coal costs of the Federal Trade Commission the average sales realization of the 812 operators reporting to the Commission for April was $3.26 per ton, while their reported f.o.b. cost amounted to $2.76. These figures are interesting to those who, notwithstanding they have contracts at much lower prices, are paying four, five or six times as much. We have yet to learn of any intelligent attempt to put an end to the conditions which permit this continued preying upon the industries of the country and upon those who buy the products of the industries. And we have yet to learn of a single instance where summary and adequate punishment has been inflicted upon those who practice it. If it is legal, there is something radically wrong with the laws. If it is legally, as it is certainly morally, criminal, there is something radically wrong with those who are charged with the administration of justice.

If it is a fact that the present high prices of coal and interruption to industry, to say nothing of the threatened shortage of the coming winter, are due to car shortage every shop in the country that can make cars ought to be running twenty-four hours a day. Are they?

CORRESPONDENCE

Recently Inspected Boilers

I recently operated a tugboat, the boiler of which was inspected and hydrostatically tested a short time ago at Buffalo, by United States inspectors. One week later I took the tug as engineer and found the crown sheet with a patch 8 in. wide by 11 in. long, placed on the inside and electrically welded. Stays were put in the patch less than ½ in from the weld. I also found three small cracks and two bags.

I made one trip with the captain who owns the tug, and he says the boiler is all right. The patch would not stay tight at 60-lb. steam, and 145 lb. is the operating pressure. What kind of inspection was it?

Syracuse, N. Y. R. G. SUMMERS.

Comparison of Pulverized-Coal Tests

Joseph Harrington's comments in the June 22 issue of *Power* regarding the comparison of pulverized-coal tests were read with interest. It is difficult to see the logic of his assertion that the fundamental principles involved in the underfeed-stoker design are incorrect. In view of the well-known part that this type of stoker has played in the progress of economically generating the ambiguous boiler-horsepower from less than the arbitrary ten square feet of heating surface (Why not measure it in boiler-heating power?), surely it should be credited for some of the most far-reaching progress made in central-station operation in the last ten years, and it has been the means of spreading a better knowledge of the fundamental principles of burning bituminous fuels than any other type of stoker in existence.

Judging from a theoretical and scientific standpoint of the fundamental requirements of burning unprepared bituminous fuels high in volatile matter content, the underfeed principle conforms admirably with these requirements and the widespread practical application of this principle, and stokers embodying the same, cannot be overlooked.

Mr. Thompson's remarks have a bearing on the true solution of any engineering problem in connection with the generation of heat, steam, or electricity. The power-plant designer and operator alike fully realize that the maximum commercial efficiency is the ultimate criterion of a piece of power-plant apparatus and that this term as applied to a stoker and its relationship to a boiler room, at large, embraces a well-adjusted relation of many independent factors, such as first cost, installation cost, cost of brickwork, combined furnace and boiler efficiency, combustion capacity, ability to efficiently handle almost any kind of coals (especially the low-grade and clinkering coals) without excessive labor, flexibility of operation, simplicity in handling, low maintenance to stoker parts as well as furnace brickwork, reliability against shutdowns, service of the manufacturer, etc.; that the best obtainable value of only one or two of these factors, if the remaining factors are not considered, will lower the value of the maximum commercial efficiency; and that to compare, say, one system of burning a particular fuel or one stoker with another on an efficiency basis alone, is, to say the least, incorrect.

If a certain method or principle of burning fuel, having all the theoretical and scientific requirements for the proper combustion of the volatile as well as the fixed-carbon portion of such fuel, yields results known in practice to be superior to any other method of burning such fuels under the same conditions, then the principle or basis of burning such fuel is demonstrated to be correct.

This principle, however, may be incorporated in a particular stoker design and give unsatisfactory results from "clinker formation, periodic dumping, uneven thickness of fire, fuel-bed disturbance, etc.," and also, as Mr. Thompson states, from the emission of "large sparks indicating the carrying away of combustible." Such results, however, are due to imperfect stoker design, not to the underfeed principle.

The gross efficiency mentioned by Mr. Harrington, is, of course, a combination of boiler and furnace efficiency at a certain rating, with a certain fuel. Such factors as boiler and furnace performance are involved in this figure and make it difficult to see the comparative value between the gross efficiency figure mentioned at the Oneida Street plant test with an underfeed stoker and a predicted future method of stoking which will produce "a gross efficiency of 80 per cent."

If I recall correctly, Dr. Jacobus' figures from tests on underfeed stokers at the Delray plant of 79 to 80 per cent gross combined boiler and furnace efficiency were obtained at 107 to 125 per cent of boiler rating during 24- and 48-hour periods with a special Stirling boiler rated at 2,365 hp., coal of the Red Jacket kind, 14,000 B.t.u., and a stoker having an underfeed-grate area of 250 square feet.

It seems that too often in our technical magazines comparative figures of performance are given which, if analyzed, are found to have no common standard of comparison, and offhand statements are made which a fair-minded engineer, or surely a competitor in a friendly way, would label as commercialism.

Frederick, Md. EDWIN LUNDGREN.

Maximum Length of Longitudinal Joints in Boiler Shells

Owing to distance, this contribution relating to the maximum length of longitudinal joints of boiler shells will be a little late, but as the subject is of interest a further discussion may not be out of place. The difficulty of the problem to determine with accuracy the stresses to which the material of a cylindrical shell is subjected by internal pressure is clearly shown by the differing opinions of various correspondents. If the common rule in designing machinery, to make it of equal strength in all its parts, were adhered to in the case of a vessel of uniform thickness of walls, the shape of the vessel would have to be that of a sphere. The form of a sphere alone remains stable under any pressure, and the strain of the material of which it consists is identically the same in every direction. Inasmuch as the shape of a cylinder differs from that of a sphere, there are different stresses working in the various directions.

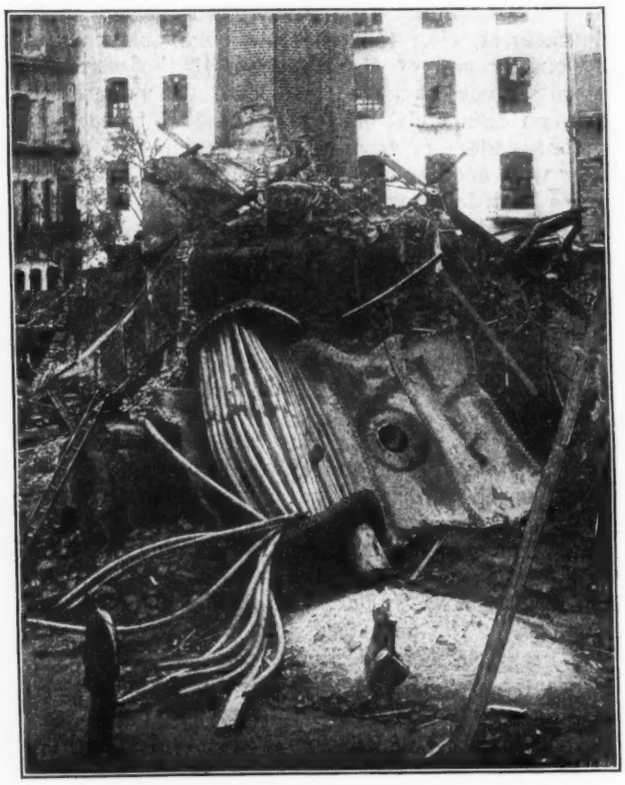


FIG. 1. NOTE THE PLATE DESIGN OF THE EXPLODED BOILER

The common methods of calculating these stresses are based upon so many assumptions that their results are highly misleading. But within the limit of elasticity a measure of the actual stresses working may be found in the deformations of the shell under pressure. By these means Mr. Stromeyer tried to solve the problem. The startling results he obtained are far from being improbable. He found that in one case the stress in the solid plate, next to the end of the longitudinal joint of the neighboring course, was eight times as great as that in parts of the solid plate farther away from the joint. But this certainly holds good only for a definite height of pressure. The proportion may be still greater at a lower pressure, while the absolute stresses may be smaller, for the stresses wander and shift with the rising pressure.

The manner in which a boilermaker handles the plates cannot be compared to that of an instrument maker. The plates of a boiler receive hard treatment when they are hammered, bent and riveted one to the other. This treatment strains the material in some parts even without any internal pressure working. These pre-existing stresses augment or reduce, as the case may be, the strain produced by the internal pressure.

Now, a cylindrical boiler shell is neither rigid enough nor so elastic that the rising strain produced by an augmenting internal pressure would be immediately transmitted to every part of the structure. The well-known noises heard when a boiler is tested by hydraulic pressure testify that one part after the other takes its charge, and there can be no doubt that in some parts the limit of elasticity will be reached and transgressed at relatively low pressures if the ultimate strength of the whole depends on the strength of all its part. A comparison may help to make matters clearer.

A weight hanging on several ropes strains them in a different measure, as it is practically impossible to get ropes of exactly equal length and of the same quality. The unavoidable differences account for the fact that as long as the weight is light, it is borne only by the shortest ropes or by those of least elongation. It is only after the stretching of these ropes that, with a heavier weight, the other ropes partake of the weight and the stresses equalize. No doubt the limit of elasticity might have been transgressed in some ropes. Furthermore, the conception of a limit of elasticity corresponds to no reality. In fact, there is no other limit but a limit to our senses and faculties of seeing and measuring. By controlling the interference stripes of monochromatic light, as Mr. Stromeyer did, the so-called limit of elasticity must have been reached at much lower values than generally assumed.

To answer the question whether long or short courses were preferable in boiler construction, let us first consider shells without any longitudinal joint. The well-known formula $S = \frac{Dp}{2t}$ applies to a cylinder of infinite length. A hose of a fire engine may serve for an example. The pressure p causes the diameter D to increase, but there is no possibility of its assuming the shape of a sphere. Should there be iron bands placed around the cylinder certain distances apart, they would prevent the cylinder from expanding at the places where they are put, by themselves taking part of the stress, while the remaining stress on the plate would not be sufficient to stretch it as much as the entire stress does in those parts where there are no rings. The stress in the plate under the ring is therefore smaller than elsewhere. The strengthening effect of each ring may even be noticeable to some extent on both sides of the ring and the stress in the solid plate midway between two rings cannot even reach $S = \frac{Dp}{2t}$, though its value would be the nearer to this limit the farther the rings are set apart. The elongation of the material being proportionate to its strain, the cylinder becomes barrel-shaped between any pair of neighboring rings. The rings cannot be considered otherwise than that they are strengthening the structure.

The overlapping ends of the plates at the circum-

ferential lapped joints or the butt-straps of butt-strapped girth joints may well be compared to such rings, the more so as the section of the doubled plate in the joint after deduction of the rivet hole is still greater than the section of the solid plate. The result of this reasoning is, therefore, that a cylindrical shell consisting of several courses riveted together by lapped or butt-strapped circumferential joints will better resist

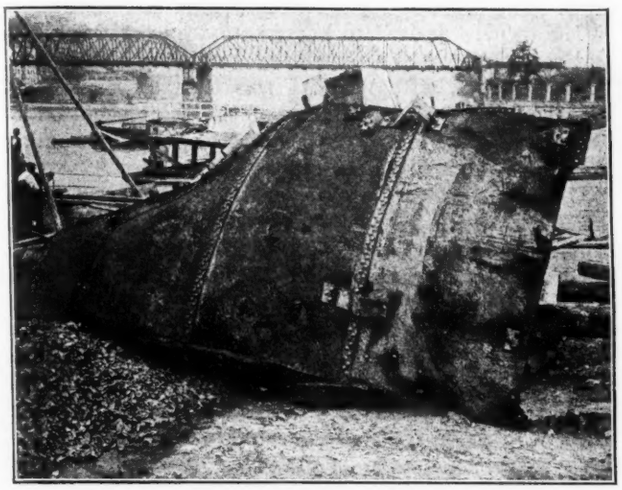


FIG. 2. EXPLODED SCOTCH MARINE BOILER

internal pressure than a drum without girth joints. The lower resistance lengthways may be left out of consideration, as circumferential joints are necessary in any case for joining the heads to the drum.

The next question is in how far this reasoning stands when there are longitudinal joints. In a drum of infinite length with no circumferential joint and one longitudinal joint, the internal pressure p would set up a strain of the material in the joint of $S = x\,\frac{Dp}{2t}$, with $x > 1$. The calculated stress in every other part of the plates and in a direction transversely to the axis of the drum would be, as formerly, $S = \frac{Dp}{2t}$. These stresses deform the cylinder, the length of which cannot any more be assumed infinite, as the one-sided weakness due to the joint would cause the curving of the cylinder, the joint being on the concave side of the curvature. There would be no curving if the cylinder had two or any even number of joints diametrically opposed to each other.

The shearing stresses set up in the plates near the seams have been explained very clearly by Mr. Stromeyer in his book, "Marine Boiler Management and Construction," and there remains hardly anything to be added in this respect. These queer shearing stresses are produced by the tendency of the strained joints to contract lengthways and to bend the cylinder. Although a symmetrically opposite joint may prevent bending, nevertheless the tendency exists and is at work. The strain caused by it is independent of the length of the seam, and in this respect a short joint is no better off than a long one. Now, as these strains are due to the stresses working transversely to the axis of the cylinder, all means that help to reduce these stresses may serve as well to reduce the strains herein referred to.

As has been shown, circumferential joints, whether lapped or butt-strapped, are a means of reducing the transversal stresses. It follows that circumferential joints must be regarded as strengthening the structure. Moreover, girth joints allow the staggering of the longitudinal seams in the courses and thereby another advantage is obtained, as part of the stress of the longitudinal joint is borne by the solid plate of the adjoining course, as Mr. Stromeyer has clearly demonstrated. The weakest points of a drum consisting of several cylindrical courses, riveted together in the usual manner, are to be looked for in the midst of the several longitudinal joints, and I think Mr. Jeter is right in assuming that a boiler tested to destruction would first give way at one of these points.

In our country every boilermaker is free to make the longitudinal joints as long as he chooses; our laws do not interfere, and if a boiler shows no signs of weakness at the official hydraulic test, there is no restriction whatever for it to be put in use.

The return-tubular boiler, so much used in the United States, is not a favorite in our country. In fact, it is regarded as rather a poor boiler. The majority of our boilers up to 1,000 sq.ft. of heating surface are of the Cornish or Lancashire type with one or two internal furnaces. Larger units of cylindrical boilers are of a combined type. Our boiler manufacturers, fully aware that the weakest points of the shell are in the longitudinal joints, try to make each course of the shell with as few longitudinal joints as possible. The weakness of a boiler shell betrays itself by the leaking at its longitudinal seams, while girth seams seldom become leaky. There is also a small difference in the tensile strength of a plate lengthwise and crosswise to the direction of its having been rolled, and for this reason there is some advantage derived by disposing the length of the plate circumferentially. Therefore, the courses of the shells of our cylindrical boilers do not generally exceed the length of six feet.

Some of the very few exceptions to this practice had very discouraging results, and the accompanying illustrations show the result of two fatal explosions that occurred some years ago with boilers whose shell consisted of only one course with four longitudinal joints of considerable length. The illustrations speak for themselves. The exploded boiler of Fig. 1 was a two-story boiler consisting of a shell with two internal furnaces beneath and a tubular boiler on top. The shell of the latter, which measured 6 ft. in diameter and 13 ft. in length, consisted of one course of plates 0.65 in. in thickness with four longitudinal double-riveted lap joints. The allowed pressure was 156 lb. per square inch.

The other boiler, the shell of which is shown in Fig. 2 after the explosion, was a Scotch-marine boiler with two furnaces; the shell measured 6 ft. 5 in. in diameter and 9 ft. in length and consisted also of only four plates, ½ in. in thickness with four longitudinal double-riveted lap joints. The boiler was considered safe for a steam pressure of 114 lb. per square inch. It carried about 110 lb. per square inch at the time of the explosion.

It is only recently that the drums of some novel types of water-tube boilers are made with continuous longitudinal butt-strapped joints, 8 and 10 ft. long. No failure of such has as yet been reported.

Vienna, Austria. FRITZ KRAUSS.

Burning Sawdust To Reduce the Fuel Bill

I thought it might be of interest and possibly of some benefit to tell the readers of *Power* what I am doing during the present serious and critical fuel situation to keep our power plant in operation and reduce running expenses.

The last car of coal we bought on contract, received in April, cost us $3.09 per ton f.o.b. mines. The next car we bought cost us $9 per ton f.o.b. mines. Our average consumption of coal is three 50-ton cars per month. The increase, therefore, in the price of coal would add approximately $900 per month to our fuel bill. This was more than we felt we could stand. Furthermore, it was almost impossible to get coal at any cost. I decided to try something that I hoped might help us out.

There were several large piles of sawdust from three to five miles distant that could be reached by an ordinary truck and I determined to rent a truck and haul this sawdust to the power plant to be used, to a large extent, as a substitute for the expensive coal. With two men on the truck we are hauling 12 tons of sawdust per day, six days per week. Now, instead of burning four to five tons of coal per day we are burning not to exceed 1½ tons. We are hauling sawdust fully 50 per cent faster than we are burning it. After we get rigged up as planned we do not believe it will be necessary to burn even one ton of coal a day. The expense of hauling the sawdust does not exceed $18 a day. We are, therefore, saving over the present prices of coal approximately $100 a week. I have been conservative in regard to the amount of sawdust mentioned as hauled.

At present we are hand-firing the sawdust, but will soon have a rig that will make it easy on the firemen. We have a blower system for conveying sawdust to our furnace from a small sawmill near by, but the sawdust we are hauling is too wet to handle with this system.

We have a dutch oven that was built under our boiler when installed to burn sawdust, shavings and peanut hulls.

There must be many light and power plants facing similar fuel conditions that should take some steps to utilize as fuel some of the immense piles of sawdust around them.

L. R. MILLS, JR.
Supt. Light and Water Commission.
Scotland Neck, N. C.

Determining Depth of Crack in Crankshaft

The letter of D. L. Fagnan on circumferential cracks in a 14-in. crankshaft reminds me of an experience. The circumstances were different from those related by Mr. Fagnan, in that there was no doubt as to there being a crack, which was gradually growing longer, and the telltale red or brown oil had continued to ooze out for some time. The crack is represented by Fig. 1.

The owners desired to know how deep the crack was and something of the remaining strength of the shaft. F. W. Salmon, with whom I was then associated, assumed that if the neutral axis of the shaft could be located, the depth of the crack could be found, assuming it to have the shape of a saw cut, as shown.

There was a heavy rope wheel on the shaft close to the crack, which had a tendency to cause the shaft to bend. The method employed by Mr. Salmon to locate the neutral axis and find the depth of the crack was as follows: He drilled and tapped a ¼-in. hole at each side of the crack, and similar holes were made diametrically opposite the first ones. Then ¼-in. rods were screwed in and a gage, such as is used in machine shops for setting up work, attached to each pair of rods and placed 8 in. from the shaft, as shown in Fig. 2.

The crack was placed on the top center and the gages read. The crack was next placed on the outer and inner centers, but the gages showed no change in reading. When the crack was placed on the lower center, the opening effect was apparent by the reading of the gages.

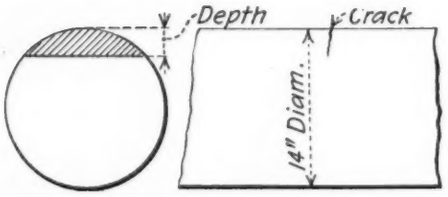


FIG. 1. SHOWING DEPTH OF CRACK

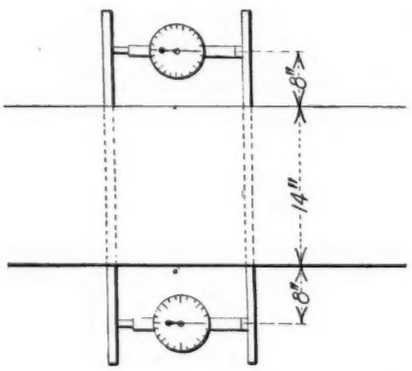


FIG. 2. POSITION OF TEST GAGES

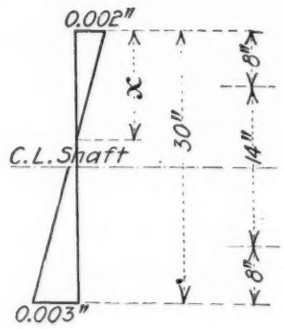


FIG. 3. POSITION OF NEUTRAL AXIS

Had there been no crack, the readings should have remained the same and the neutral axis would be at the center of the shaft. Suppose the difference between the original readings of the gages and the readings with the crack on the lower center were 0.002 in. for the top gage and 0.003 in. for the bottom one, Fig. 3. Then the neutral axis is found from the equation,

$$\frac{0.003}{30-x} = \frac{0.002}{x} \qquad x = 12\,in.$$

The neutral axis would be 15 — 12 = 3 in. from the center of the shaft.

I do not remember the readings of the gages or the depth of the crack, but I know that Mr. Salmon recommended a new shaft, and I checked analytically the depth of the cut and computed the strength of the shaft in bending and in torsion.

INQUIRIES OF GENERAL INTEREST

Semi-Steel—What is the material that is known as semi-steel? R. N. B.

So-called semi-steel is a special kind of cast iron produced by adding to the molten cast-iron scraps of wrought iron or steel by which the strength and toughness of the cast iron is increased, making it suitable for many purposes where more expensive material would be required.

Falling and Rising Exhaust Line—What is indicated by falling and rising of the exhaust line of an indicator diagram? M. S.

A falling and rising exhaust line may be due to contracted exhaust ports or pipes that do not allow the steam to pass out as rapidly as it is displaced by the piston at its greatest velocity, thus creating greater back pressure toward the middle of the stroke; or a rise of pressure may be due to leakage of the piston or steam valve.

Air Contained in Steam—Does steam contain the same amount of air as the water from which it is generated, or is there a different amount present? J. H. B.

When water is heated to the boiling point, practically all of the air becomes liberated and that weight of air is present as a mechanical mixture with the steam at the same pressure. When the steam is condensed to water, nearly all of the air that was mixed with the steam becomes disengaged as air saturated with moisture, the amount of moisture depending on the temperature at which condensation takes place.

Negative Lead—What is meant by negative lead, and how would a valve be set to give negative lead? F. J. G.

Lead is the width of port opening when the crank is on dead center, and negative lead would be the amount the valve overlaps the admission edge of the port when the crank of the engine is on dead center. To set a valve with the same amount of negative lead at each end, turn the engine over and lengthen or shorten the valve rod, as may be necessary, to obtain the same travel of each end of the valve beyond the admission edges of the ports. Then place the engine on a center and set the eccentric in such a position that the valve overlaps the admission edge of the port for forward rotation by the amount of negative lead that is desired.

Formula for Computing Pump Capacity—What is a simple formula for estimating the capacity of a pump? W. L. A.

The capacity of a single, double-acting pump can be calculated theoretically by the formula

$$Q = \frac{a \times F \times 12}{231}$$

where Q = displacement of one double-acting plunger in U. S. gallons, a = area of plunger in square inches, and F = piston speed in feet per minute.

Where d = diameter of plunger in inches, the formula becomes

$$Q = \frac{d^2 \times 0.7854 \times F \times 12}{231} \text{ or } Q = 0.0408\, d^2 F$$

For actual capacity the displacement by the piston rod and percentage of slip of the pump must be deducted.

Removing Grease from New Boilers—How can oil and grease be removed from a new boiler before it is put in service? J. S. A.

Place in the boiler about half a pound of soda ash per horsepower capacity and, with the boiler filled with clean water to the highest gage cock, start a slow fire. After holding the water to the boiling point for about twelve hours, allow the fire to die out and the boiler to cool slowly, after which drain the boiler and then open it and wash out thoroughly.

Sling Stays of Internally Fired Boilers—What are sling stays, used in construction of internally fired boilers? R. G.

In locomotive and marine types of boilers, where girder stays are used for supporting the crown sheet or top of the combustion chamber, the girder stays, in addition to having end supports, are commonly supported at intervals of their span by short articulated stays, called sling stays, fastened to the girder and top of the boiler. The required depth of the girder stays is thereby reduced, and with the crown sheet suspended from the girders the staying is equivalent to having a flexible arrangement of through stays from the crown sheet to the top sheet of the boilers.

Sizes of Tubes for Return-Tubular Boilers—What determines the sizes of tubes suitable for a horizontal return-tubular boiler? W. A.

The most suitable size of tubes depends on their length, the kind of coal to be burned, the facilities for cleaning and the force of the draft. The smaller the tubes the greater the total heating surface for the space occupied, but the more easily they clog with soot and choke the draft. The larger the flues the less the heating surface for a given amount of tube space and less efficiency of heating surface. For operation with natural draft a common rule is to allow one inch of nominal diameter for each four feet of length for use of bituminous coal or for each five feet of length for anthracite. With forced draft and frequent cleaning smaller tubes can be used.

Testing for Engine Oil in Feed Water—What simple test can be made to determine whether boiler-feed water contains oil from the engine? W. E. D.

The presence of grease or oil in water will be shown by addition of caustic soda. Prepare about one-half pint of concentrated solution of caustic soda, and in separate clear glass vessels take the same quantities of the raw water and of the feed water supposed to contain engine oil. With a measuring beaker determine how much of the soda solution must be added to the feed water to produce a milky precipitate. Add the same quantity of the soda solution to the sample of raw feed water and then by adding engine oil drop by drop until the sample of raw water has acquired the same turbidity as the sample of feed water, it may be approximately found what equal quantity of oil has been picked up by the sample quantity of feed water.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. —Editor.]

Limitations to High Vacua*

By A. B. BAILEY†

The question of high vacuum has interested plant operators recently especially on account of the more efficient air-removal devices used. The tendency toward the use of high-vacuum condensing equipment has been continually to demand higher vacuum with the idea that this means greater economy. Under ordinary conditions this is admittedly true, but the conditions under which greater vacua could be obtained introduce a number of factors that may more than offset any possible gain in economy.

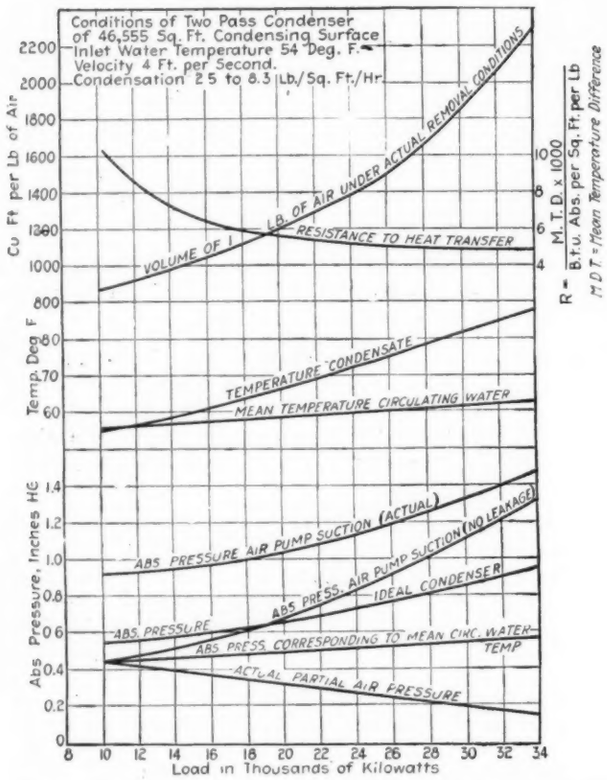

Conditions of Two Pass Condenser
of 46,555 Sq. Ft. Condensing Surface
Inlet Water Temperature 54 Deg. F.
Velocity 4 Ft. per Second.
Condensation 2.5 to 8.3 Lb./Sq. Ft./Hr.
Cu Ft per Lb of Air
Temp Deg F
Abs Pressure, Inches HG
R = B.t.u. Abs. per Sq. Ft. per Lb / M.T.D. x 1000
M.D.T. = Mean Temperature Difference
VOLUME OF 1 LB. OF AIR UNDER ACTUAL REMOVAL CONDITIONS
RESISTANCE TO HEAT TRANSFER
TEMPERATURE CONDENSATE
MEAN TEMPERATURE CIRCULATING WATER
ABS. PRESSURE AIR PUMP SUCTION (ACTUAL)
ABS. PRESS. AIR PUMP SUCTION (NO LEAKAGE)
IDEAL CONDENSER
ABS. PRESSURE
ABS. PRESS. CORRESPONDING TO MEAN CIRC. WATER TEMP
ACTUAL PARTIAL AIR PRESSURE
Load in Thousands of Kilowatts

FIG. 1. THE CURVES SHOW THAT THE AMOUNT OF AIR TO BE REMOVED IS MORE AT LOW THAN AT HIGH LOADS

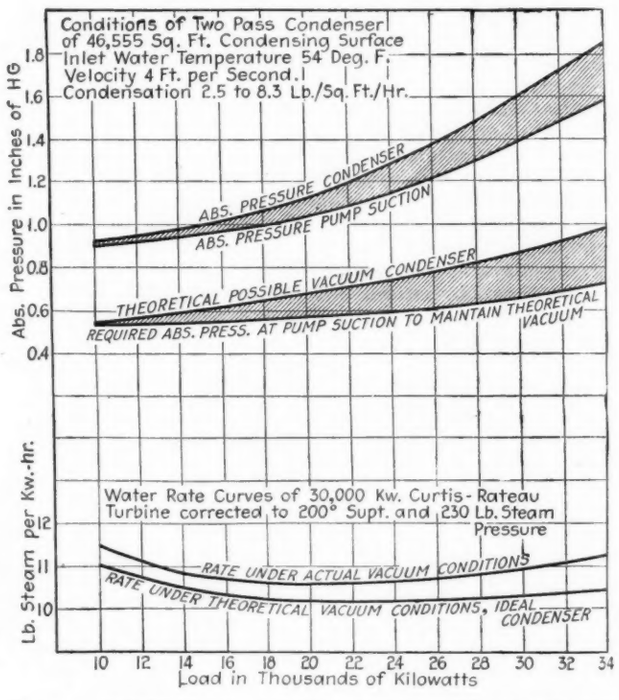
It appears that a large number of plant operators have gone on demanding higher vacuum under their present equipment without regard to the difficulties to be overcome. Others have maintained that there is a definite limit to the vacuum obtainable beyond which it would not pay to go. The former advanced the usual theoretical reason for higher vacuum, but produced no actual data to substantiate the claims, which for this reason are nothing more than professional opinions.

On the other hand, the claim that there is a definite limit to economical vacuum has at least partial substantiation by experiment on equipment as it is, but this does not necessarily indicate the possibilities of a turbine-condenser equipment designed originally for high vacuum. By high vacuum is meant an approach to the conditions of an ideal condenser working under average conditions as to temperature and velocity of circulating water.

As no real data are available to show just what are the limitations of maximum economical vacuum, the discussion here is confined mostly to the problems that future developments must overcome in approaching the conditions of an ideal condenser. It is ordinarily considered that higher vacuum is a function of the condenser only, but as a matter of fact it involves not only this but the design of the turbine, particularly the final expansion stages, tightness of turbine casing and condenser and the ability to remove highly rarefied air.

For the purpose of illustration in this discussion the conditions of a surface condenser operating in connection with a 30,000-kw. Curtis-Rateau turbine are used and shown in Figs. 1 and 2. These conditions can be considered as present good practice, and the opportunities for and chances of further development are as good as with other types of generating units, or possibly better.

One of the most important factors governing the maximum vacuum possible is, of course, the amount of air to be removed. So condenser manufacturers claim that the amount of air to be removed from a condenser is directly proportional to the steam condensed. This may be true of a tight condenser wherein all the air enters by entrainment with the feed water. Actual operation shows that a tight condenser and exhaust casing is a rare condition. Referring to Fig. 1, it is shown by the curves of partial air pressure and resistance to heat transfer that the amount of air to be removed was not proportional to the steam condensed, but actually more at low loads than at high loads. This fact is an indirect indication that the air in the condenser was largely a matter of leakage, instead of entrainment with the feed water. Thus it can be seen that a condenser that is tight under all loads and temperature conditions offers opportunity of increased vacuum. The vacuum conditions of no air leakage or entrainment are shown in Fig. 1 for all load conditions. This is probably impossible of attainment, but there is still a chance of improvement in this respect.


Conditions of Two Pass Condenser
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Inlet Water Temperature 54 Deg. F.
Velocity 4 Ft. per Second.
Condensation 2.5 to 8.3 Lb./Sq. Ft./Hr.
Abs. Pressure in Inches of HG
Lb. Steam per Kw.-hr.
ABS. PRESSURE CONDENSER
ABS. PRESSURE PUMP SUCTION
THEORETICAL POSSIBLE VACUUM CONDENSER
REQUIRED ABS. PRESS. AT PUMP SUCTION TO MAINTAIN THEORETICAL VACUUM
Water Rate Curves of 30,000 Kw. Curtis-Rateau
Turbine corrected to 200° Supt. and 230 Lb. Steam Pressure
RATE UNDER ACTUAL VACUUM CONDITIONS
RATE UNDER THEORETICAL VACUUM CONDITIONS, IDEAL CONDENSER
Load in Thousands of Kilowatts

FIG. 2. SHOWING THE PUMP SUCTION AND CONDENSER PRESSURES FOR ACTUAL AND THEORETICAL CONDENSERS

A limiting factor of actual vacuum is the temperature of the condensate, inasmuch as a vacuum greater than that corresponding is impossible. It has been claimed that there were high vacuum possibilities in reducing the condensate temperature, the limiting possibilities of which would be a mean of the circulating-water temperature. Referring to Fig. 1, this hypothetical vacuum is greater than that possible with an ideal condenser operating under

*Presented at the recent convention of the National Electric Light Association, Pasadena, Cal.

†Chief engineer, Fiske and Quarry Street Stations, Commonwealth Edison Co., Chicago, Ill.

the conditions stated and is, therefore, impossible. Any gain in economy resulting from increasing the vacuum by reducing the condensate temperature would have to do more than balance that lost through the feed-water temperature. A heat balance shows only slight possibilities at high load.

The most important limitations to high vacuum have to do with the design of the turbine itself, which is designed for a definite vacuum at its most economical load. The volume of a pound of steam at 1 in. abs. is 652 cu.ft., and at 0.5 in abs. is about 1,260 cu.ft.—almost twice the volume. On the present equipment this would mean a corresponding increase in the exit velocity for the last row of buckets, which means a large increase in the lost kinetic energy, this being in proportion to the square of the velocity. Such incomplete data as are available show that at loads from 10,000 to 12,000 kw. (see Fig. 2) there is an increase in economy of about 3 to 3½ per cent, while at higher loads no increase is indicated over a range of 1 in. to 0.5 in. abs. These percentages at 0.5 in. abs. were, however, assumed, as actual conditions of 0.5 in. abs. condenser pressure could not be obtained.

Turbine-bucket design requires that the speed of the bucket bear a proper relation to the steam velocity. If this relation is to be carried out under high vacuum conditions, difficulties of design in the last stage of buckets nullify any possible gain in economy. If buckets are made too long, the velocity conditions on account of the flare would be such that steam would blow through without doing any work.

If high steam velocities are used in the last stage, it must necessarily follow that a greater proportion of the work done must be accomplished there; and this would mean less efficiency than if designed for a lesser proportion of work.

It would then appear from the foregoing that there are limitations to economical vacuum, but owing to the lack of complete data pertinent to this question, no exact limit or any set of conditions can be stated at this time. It does not appear that the conditions of an ideal condenser or vacuum of from 0.5 in. to 0.9 in. under the conditions as shown by Fig. 1 are impossible of attainment if increased economy is the governing factor.

An Experimental Investigation of Steel Belting*

Attention has been called from time to time to the successful use of thin ribbons of steel for belting, and the experiments here described were undertaken to determine the characteristics of operation of this type of power transmission.

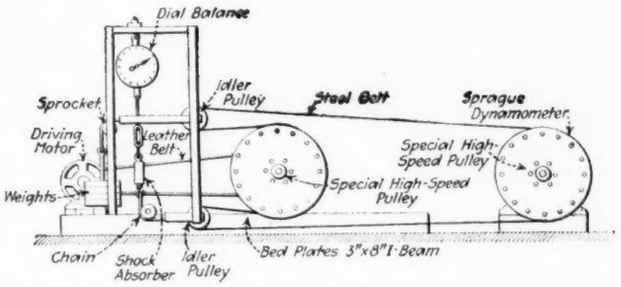
The apparatus designed for testing is shown diagrammatically. Two specially built high-speed pulleys with sheet-cork facing were arranged as shown, the driven pulley being directly connected to a Sprague dynamometer. Two idler pulleys running on ball-bearing axles were arranged to measure the tensions in the belt. The idler on the tight side was held by a yoke to which was attached a short chain passing over a sprocket and carrying a scale pan on which weights might be placed. The loose-side idler was carried by a similar yoke with a chain and sprocket, the chain passing vertically upward and being connected to a dial spring balance. Between the chain and dial balance was placed a spring balance to act as a shock absorber and a turnbuckle to adjust belt tensions.

The two pulleys being of the same size, the introduction of the idlers prevented the two sides of the belt from being parallel, and therefore the tensions were not equal to the values indicated by the weights or dial balance. This was corrected for by preliminary tests in which a spring balance was inserted in the belt and readings taken while rotating the whole apparatus slowly. From these readings plots of actual tensions against readings of the dial balance and the amount of weight on the scale pan were made.

The material tested was what is known commercially as clockspring stock. It is a very high-carbon steel, drawn and rolled, apparently ground to size, hardened and drawn to a dark blue color. A rough test showed a tensile strength of 300,000 lb. per sq.in. and an elastic limit nearly as high. Pieces 0.01 in. thick receive no permanent set when bent around a radius of ½ in., but break clean when bent around a radius of $\frac{1}{16}$ in.

The chief difficulty in using such material for belting is to get a joint having a reasonable proportion of the strength of the material. This was further complicated in the tests by the necessity for the reverse bending of the belt around the idler pulleys. A plain butted joint held with silver solder was found satisfactory, although the short time it was in use gives no indication of its durability.

Tests were run keeping the speed and tight-side tension constant and varying the load. Loads were increased until the loose-side tension became so low as to allow the belt to become unstable. After covering the possible power



EXPERIMENTAL APPARATUS FOR TESTING STEEL BELTING

range, the tight-side tension was changed and another series of tests was run. Finally, speeds were changed for further runs.

In the first part of the paper, describing tests by Messrs. Hampton and Leh, it is pointed out that the slip was determined from differences of readings on revolution counters attached to the driving and driven shafts. The error introduced by this method in some cases was as much as 100 per cent of the slip, although the absolute values of revolutions per minute were determined with reasonable accuracy. In later experiments by Mr. Helmick, a differential revolution counter was connected to the two shafts by chains and sprockets and arranged so that differences of $\frac{1}{100}$ revolution would be indicated by the ring gear, with a probable error of 5 per cent.

The difficulty of measuring the velocity of slip led to considerable study to discover the laws governing the relation of slip to the various other quantities involved. It was found that at a given speed and tight-side tension the slip increased slowly, but in direct proportion to the horsepower to a certain point, beyond which it suddenly increased very rapidly. Further investigation showed that this point corresponded to that at which the tension due to centrifugal force equaled the slack-side tension, loads beyond this of course resulting in excessive slip and unstable conditions.

As a result of the entire investigation the authors suggest that the equation $Hp. = 0.17T_1^{0.65} V_s$ (where T_1 is the tight-side tension in pounds and V_s the velocity of slip in feet per minute) may be useful in determining the tight-side tension for a given horsepower transmission with a reasonable slip (not greater than 3 ft. per min.). Knowing this tension, the belt may be cut to length by computing the total elongation due to tension and the distance the cork will be depressed.

Considerable study was made of the relations of the coefficient of friction to the various other factors and equations deduced which are mainly of technical interest. It is noted that the efficiency of transmission fell below 98 per cent only in extreme cases.

*Abstract of a paper by F. G. Hampton, C. F. Leh and W. E. Helmick, for which the authors were awarded the Student and Junior prizes at the annual meeting of the American Society of Engineers in December, 1919. The complete paper was published in the July, 1920, issue of *Mechanical Engineering*.

Fuel Oil in Steam Plants*

By Edward H. Colegrove

In buying oil certain specifications are made. The following are fairly indicative of the demands made for a good grade of fuel oil: Specific gravity not over 0.96 nor under 0.85 at 59 deg. F.; B.t.u. not less than 18,500 per lb.; water not over ½ of one per cent; sulphur not over 2 per cent; dirt and sand, none.

The flash point of an oil is the temperature at which vapor is given off which in a closed container will ignite. The flash point of an oil should not be under 140 deg. F. Oil varies considerably in viscosity; that is, some oil flows through a pipe like cold molasses, and other oil flows like hot molasses. Very viscous oils will need to be heated to higher temperatures than thin oils for easy flow.

If oil burning is to be introduced into a plant, it is of course necessary to make provision for storing and handling it, safely and economically.

It is usually necessary to have storage space for three weeks' supply. The storage tanks are either of cement or of steel. In New York State the insurance regulations require that they be not less than 2 ft. under ground and 50 ft. from any building. Some authorities recommend that two tanks be used, so that one may be available for use while the other is being cleaned or repaired.

The highest level of oil in storage should be below the lowest point in the piping of the oil system to prevent flooding of the burners in case of accident. The tank should be vented to allow the vapor to pass off. Steam lines are often piped to the top of the tank that possible fires may be extinguished. All oil piping should be installed so as to drain back into the storage tank by gravity. Arrangements should be made to deliver oil at the burners at constant pressure. This can be effected by a standpipe. The connections for the delivering car or wagon should be at sufficient elevation to overcome the head of water to the desired height of oil in the tank.

Joints in Piping Must Be Tight

Because of the penetrative nature of fuel oil all joints in the piping must be made tight. If possible, elbows should be avoided in oil piping, as foreign matter will collect at these points and eventually clog the pipe. It is best to use bends of long radius and arrange a steam connection so the pipes when drained may have steam sent through them to blow out the asphalt or tarry matter.

As most burners atomize oil by forcing it through small orifices, an efficient strainer is needed in the feed line. The duplex thimble type is excellent, as one strainer can be removed and cleaned without affecting the pressure while the oil is passing through the other.

As hot oil flows more easily, atomizes more readily and burns better than cold oil, it will be appreciated that an oil heater is necessary to furnish the oil to the burner at a temperature of from 125 to 140 deg. F.; that is, just under the flash point. Care should be taken not to heat the oil above the flash point, as excessive heat precipitates the carbon in the pipe lines and at the burner tip, and should even small leaks develop in the oil lines, explosions would be likely.

Broken into small drops, oil presents a large surface. The smaller the drops the more perfect the spheres and the easier to burn. If oil is broken into drops 0.1 in. in diameter the ratio of the area to the volume is 60 to 1, but if broken into drops 0.01 in. in diameter the ratio of area to the volume of the original drop is 600 to 1. That is, a drop 0.01 in. in diameter exposes ten times as much surface in proportion to its volume as a drop does which is 0.1 in. in diameter. The spray entering the furnace should be almost too fine to be seen. The economy of a burner is measured by the amount of steam used to atomize a pound of oil. This will vary considerably with type of burner, kind of oil, temperature, etc. At one of the Standard Oil Co.'s plants recent tests showed a variation from 1.36 to 3.39 per cent of total steam used for atomization. It will often go higher, from 5 to 10 per cent.

Burners are often located in the front of the furnace; sometimes the burner tip is housed in a recess in the bridge wall and the oil projected forward. The first pass should be directly over the furnace, that the heating surfaces may absorb the radiant energy of the incandescent firebrick. Oil burners may be grouped into three classes: (1) Mechaical spray, in which the oil, previously heated to about 130 deg. F. is forced through nozzles in such a way as to break up the oil into a fine spray, usually by giving it a spiral motion. 2. Vapor burners or carburetors in which the oil is volatilized in a heated chamber and then admitted to the furnace. This burner is seldom used except for refined oils. 3. Spray burners are by far the most common. In these the oil is forced into the furnace by steam or compressed air. There are two types, "outside" and "inside" mixers, the name explaining where the atomization takes place. The weight of authorities seems to be in favor of the outside mixer.

Design of Furnace Depends Upon Type of Boiler

The design of the furnace must in a measure depend on the type of boiler, and in oil burning the forms of furnaces are numerous. The basic idea should be to give the oil room to thoroughly atomize and mix with the oxygen without striking the heating surfaces, and to have the oil projected into the furnace in such a manner that the air supply will be available along the path of the flame as needed. If the air can be preheated, it will, of course, aid combustion.

One consideration of the size of the combustion space is that incandescent walls of the furnace assist materially in the combustion of the oil. In burning oil furnace volume has the same relation to boiler steaming capacity as the grate area has in a coal-burning installation. The consideration should properly be of "effective furnace volume," or that part of the furnace actually occupied by burning gases.

With water-tube boilers the burners ordinarily discharge into one combustion chamber. Here eddies of gas and the interference one flame gives to another are not always indicated by the draft gage, but no doubt affect air admission and control. For example, with a furnace with four burners properly installed as to space and air control, each having a furnace volume of 60 cu.ft., operating at ½-in. draft at the damper, a certain maximum boiler capacity can be reached when all four burners are used. This capacity cannot be increased 25 per cent by placing in service a fifth burner of the same size with a like air opening. On the other hand, if only three burners are installed instead of four, size of burner and air opening for each the same per burner, the capacity will be more than 75 per cent of the capacity attained with four burners. This is because each burner now has 80 cu.ft. of furnace volume instead of 60.

The furnace volume should be sufficient to permit complete combustion and not give the gases too rapid a flow through the furnace, as this will result in the formation of CO instead of CO_2 with the resultant heat loss.

How the Amount of Air Affects Efficiency

A slight difference in the amount of air used may mean a great loss in heat units. It is comparatively easy to have a smokeless fire, but the efficiency will greatly increase if the proper amount of air is used. "In ordinary operation the complete absence of smoke is viewed with suspicion. Smoke may result from other causes than lack of air, for instance, imperfect atomization. Analysis of the escaping gases is the only sure way of obtaining information by which to adjust the furnace conditions to maximum efficiency," said E. H. Peabody at the International Engineering Congress. "Taken by itself the gas analysis indicates better than any other one thing about a boiler plant what sort of economic results are being attained."

If insufficient air is given the flame CO is formed instead of CO_2 and about two-thirds of the heat units are wasted. Some firemen attempt to fire oil and gage the air supply by the eye. Some time ago in a Texas plant in which oil had been burned for several months where the operation depending on the judgment of the firemen, a CO_2 recorder was connected to a furnace. The firemen were instructed to

*From a paper before the Buffalo Association (N. Y. No. 16) of the National Association of Stationary Engineers.

continue to fire to the best of their ability, adjusting the oil feed and damper as they thought best. The recorder was covered over so the record could not be seen. After a period of time the recorder was uncovered and indicated 8 per cent CO_2 for the time. Then with the recorder uncovered, by watching the record the same firemen were immediately able to make 14 per cent CO_2. The recorder was evidently saving about 12 per cent of their oil.

Beginners often think that a white flame indicates economical combustion. It does not but indicates excess air. The color of the flame in best combustion is usually yellowish white. The combustion of oil is accompanied by a roaring noise. It is noticeable that an increase of cold air adds to this noise, and that preheating the air renders combustion quieter. It is therefore believed that this decreased roaring is accompanied by increased efficiency.

If wet steam is used, the moisture should be removed and, better still, superheated before it reaches the burners. Every drop of water that goes into the furnace will pass out as superheated steam and carry with it that much heat. In some installations the steam line to the burners passes through the combustion chamber and superheated steam is delivered in that way. If not convenient to superheat, it will be well to place a steam separator in the line to the burners so the steam used will be free from moisture. The idea that steam admitted to the furnace with the fuel increases the amount of heat generated is an error. The amount of heat resulting from the burning of the hydrogen in the steam is precisely equal to the amount of heat required to set the hydrogen free in decomposing the steam.

Automatic control is employed in some large plants and is accomplished in a manner somewhat similar to the familiar damper regulators. The steam pressure controls the rate of oil feed as it does the damper for draft.

Damper Should Be Used To Regulate Air

It is good practice to use the damper to regulate the supply of air. If ashpit doors are left wide open all the time a sufficient air supply is assured to take the place of the hot gases which escape up the chimney. By impeding the flow of hot gases with the damper, they are kept in contact with the heating surfaces for a longer time and the retarded gases are given plenty of time for complete combustion.

When shutting down the oil should be cut off first; this stops combustion. The steam should be allowed to flow after the oil is cut off, then gradually cut off. This tends toward leaving a clean burner.

The work of firing oil requires no physical exertion. Common sense, a certain knowledge and a watchful eye on the instruments are all that is required. A better class of men are attracted to the plant. The oil-burning more than coal-burning plant gives a fireman time to look to improvement in himself and his plant. This attracts intelligent firemen and no doubt accounts for a great part of the efficiency in oil-burning installations.

The back damper should always be left open enough to allow the gas to escape should a burner snuff out, otherwise a serious explosion might occur. Where oil is used, it is well to have one coal-fired boiler in which steam can be raised to at least 20 lb. to start the burners. It is well also that an auxiliary coal fired boiler be retained in case the oil supply fails for a time.

When the change is made to oil with horizontal tubular boilers, firebrick may be laid on the grates and a floor of firebrick continued to the rear of the boiler with only a slight rise at the point where the bridge wall was located. This makes the bottom part of what was formerly the combustion chamber combined with the space formerly the ashpit, into a space through which air for combustion may be drawn and preheated by the hot brick above. An opening is then made at the rear of the setting to admit the air, which flows through the grates to the flame.

There is but little data on the cost of changing from coal to oil burning, not even on the cost of construction of the storage tanks. In nearly all cases, however, the cost has been far in excess of the estimated cost. The question of change can only be determined in each plant by itself. The load factor evidently has a bearing on this decision. A Philadelphia engineer of prominence believes that plants that have a load factor of 60 down may change to oil advantageously, but for those with a load factor above 60 coal is more economical.

The present cost of oil in central New York State is too high to make it look attractive. To be a satisfactory fuel, oil must be available not only in large quantities but must be continually available to prevent operation ending suddenly.

Power-Station Design in Relation to Thermal Efficiency*

The paper recites a few of the lines along which modern power-plant designers have worked in an effort to increase thermal efficiencies. The manufacturers of apparatus are responsible for progress in increasing the range of temperature in saving or reclaiming low-grade heat and an increased size of units.

The upper temperature limit has been gradually raised to 650 or 700 deg. F with a comparatively wide range of pressure obtained by varying the amount of superheat. Increase of pressure with a constant maximum temperature, obtained by reducing the superheat, is advocated as giving a greater heat drop. This also results in greater steam density and therefore allows smaller piping and fittings. Pressures of 500 lb. with temperatures as high as 700 deg. F. are predicted for the near future. The lower temperature is limited by considerations of the expense of maintaining high vacuums.

Saving low-grade heat has been attempted in two ways: (1) By heating the condensate to higher temperatures, using steam tapped from the main turbine, and (2) by reheating the steam after partial expansion until the initial superheat is restored. Assuming 10 per cent of the turbine steam withdrawn at suitable points, the condensate temperature might be raised by 100 deg. F. with a saving of about 1,000 B.t.u. per pound of tapped steam. With 23 per cent of the steam tapped out, the condensate temperature rise might be as much as 225 deg. F. The effect is a slight improvement in spite of the loss of efficiency in the low-pressure blades.

The second method—reheating the steam—has been tried experimentally, but does not seem to promise much commercial success.

The size of turbine discs is limited by transportation as well as mechanical difficulties. An examination of thermal and financial considerations indicates about 30,000 kw. as the maximum desirable capacity for a single unit with plants of 180,000 kw. load and 240,000 kw. installed capacity.

As to methods of driving auxiliaries the use of an electric drive with a separate turbo-driven generator exhausting to a surface feed-water heater is thermally the most efficient, for in this case all the latent heat of the auxiliary turbine is saved. Other methods give reasonable results and are sometimes dictated by circumstances.

The material of which turbine blades are made is an item in maintaining the efficiency of the machine against loss due to erosion and corrosion. For moderate steam velocities and stresses standard 70/30 bronze is satisfactory, while 3 per cent nickel steel is successful at higher velocities and stresses.

In condenser air-pump calculations it is customary to credit steam-ejector pumps with all the heat in the discharged steam which may be returned to the boiler in the feed water. The author claims that the usual boiler losses are involved in the raising of any steam, and therefore all the heat is not reclaimed by condensing the steam from the jets.

The paper concludes with a discussion of turbine efficiencies at various loads under guarantee tests and suggests that a Willans line be drawn for the over-all fuel consumption of the plant so that steam requirements may be predicted for various conditions.

*Abstract of a paper by I. V. Robinson, read at the Incorporated Municipal Electrical Association Convention at Bradford, England.

General Precautions in Gas-Piping Work

The National Fire Protection Association Committee on Gases has reported a gas-piping code which was adopted at the recent meeting of the association and presumably will form the basis of the National Board of Fire Underwriters' requirements for gas piping of buildings hereafter. Those who desire full information at an early date can best secure copies of the code from the 1919 and 1920 reports of the National Fire Protection Association, 87 Milk St., Boston.

The general precautions that should be observed in such work are well summarized in rule 3 of this code, which is as follows:

3. GENERAL PRECAUTIONS.

a. Work with Gas Off—Gas-fitting, appliance installation and repair work shall be done with the gas turned off so that the danger from leakage during the work will be a minimum, except as provided in paragraph b.

b. Working on Pipes Filled with Gas—Work which involves removal of an appliance or unscrewing of a cap, plug or pipe which will open an outlet and permit the escape of gas should never be done without shutting the gas off, except in emergency cases where interruption of the service is impracticable, and unless the work can be done without danger to life and property with the gas on.

It is suggested that when working on pipes filled with gas, outlets larger than ¾-in. size and pressures in excess of 10 in. of water be not handled except by a specialist. In any event the following precautions shall be observed:

1. Determine the location of the meter cock or line cock by which the gas supply to the proposed opening is controlled and see that it is in working order.

2 Make sure that no fire or flame or spark-emitting device of any kind is near enough to set fire to the gas which may escape.

3. Determine that even the slight escape of gas expected will not be injurious to persons, especially invalids or small children.

4. Examine the threads to be used, to make sure the opening can be quickly and tightly closed.

5. Have at hand a plug of rubber or other suitable material to fit snugly into the opening.

6. Make sure that no lighted burners or pilot lights supplied from the line to be opened are turned so low that they may go out or flash back because of the sudden drop in pressure in the pipe when it is opened.

After the work has been completed, all appliances shall be examined and any pilot lights and burners which may have been extinguished relighted or turned off.

c. One Man Shall Not Work Alone—In any one of the following conditions there shall be more than one man present, one of whom should be in such location that he is not exposed to any possible asphyxiating influence from the escaping gas:

1. When necessary to make installations, repairs, or do other work on piping filled with live gas.

2. When work is done in a gassy atmosphere.

3. When work is done in any confined space where gas may accumulate or in any space not readily accessible; for example, where the gasfitter must lie down or assume a cramped position.

d. Use of Matches, Candles and Flames—No matches, candles or flames or other sources of ignition shall be used by a gasfitter or his helper when working on meters, piping or appliances filled with gas, except for such work as necessarily involves the use of such flames. A flame shall never be used in searching for leaks. In no case should a flame be allowed to touch a meter, meter connection or other piping. When an open-flame light, as a match or candle, is used in a basement, it should, when practicable, be carried or set not more than three feet above the floor level.

e. Smoking—A gasfitter shall not smoke while working on piping which is filled with gas or has been filled with gas, nor permit others to smoke while near such work.

f. Safety Lights to Be Provided—Every gasfitter shall be provided with an approved electric flash lamp or safety lamp which is adequately protected to prevent explosion or fire if used in a gassy atmosphere. No other type of lamp shall be used in such atmosphere when searching for a leak or when working on piping filled with live gas.

g. Handling Combustible Liquids—Alcohol, gasoline and other combustible liquids, including the liquid which is removed from meters or from drips in gas piping, shall be handled with proper precautions and shall not be left by the gasfitter on the premises of the customer. The ordinary fitter's torch or furnace shall not be left within the premises from the end of one working day to the beginning of the next unless the torch or furnace is of an approved type or is placed in a fire-resistive receptacle.

Shunt- or Compound-Wound Exciters*

By J. T. Barron and A. E. Bauhan

Wherever it is necessary that exciters be operated in parallel, it is recommended that shunt-wound exciters be used, especially if they are to be controlled by voltage regulators. The instances of compound-wound exciters causing trouble are so many that in spite of all the explanations of causes that are given, it is difficult to convince an operating man that has been through any of these experiences that compound-wound machines should ever be used where the exciters are operated in parallel.

If the saturation curves and voltage characteristics of the exciters being operated in parallel are identical and if the equalizer conditions are perfect, there is no difficulty. However, regardless of the care which may be taken in obtaining these conditions when the exciters are installed, there are disturbing influences which may occur later to interfere with the perfect conditions. For instance, equalizer switches may develop high contact resistance. Equalizer connections may be taken down and carelessly reconnected. Saturation curves of exciters may be changed by putting shims under field poles or by taking them out on account of some commutation trouble, the effect on parallel operation being forgotten. The speed of an exciter may be changed from that at which it was intended to be operated. This may be due to carelessness of attendants in not having machines operating at correct speed, or it may be due to some trouble in the turbine such as ice, or may occur from power-system troubles in the case of motor-driven or direct-connected exciters. All these conditions tend to change the shape of the saturation curves, and if operating under the influence of a voltage regulator, reversal is likely to be caused. The compound-wound exciter is also subject to reversal due to internal short-circuits. Loss of exciter shunt field may also cause reversal of compound-wound exciters. If the driving power of a compound exciter is lost, the tendency will be for the exciter to speed up and draw a heavy current, and it may even run away if not prevented from doing so by a reverse-current relay or overspeed trip.

It is therefore recommended that only shunt-wound machines be used where exciters are to be operated in parallel and that wherever compound-wound exciters are at present so used, especially in connection with voltage regulators, steps be taken to remove the series windings if the characteristics of the machines permit. The series windings should be cut out of the circuit but not short-circuited. A short-circuited series winding causes sluggish regulator action. Where exciters are to be used individually with voltage regulators, there is no objection to the series winding. It is then an advantage from the standpoint of voltage regulation.

Shunt-wound exciters also are subject to reversal from induced voltages in generator fields, regardless of whether they are operated in parallel or not. The induced voltage may be caused by a short-circuit on the generator or by sudden reduction of its field current. These two causes may work simultaneously in direct-connected exciters. Sudden reduction of field current may be caused by sudden reduction of exciter speed, by rapidly cutting in a generator field rheostat with too large steps, or by rapid reduction of exciter field current when operating on the steep part of the exciter saturation curve. If the resultant induced voltage in the generator field exceeds the exciter voltage, reversal will occur. The greater the resistance in the field circuit the less is the likelihood of reversal.

*Abstract from a paper, "Considerations Which Determine the Selection and General Design of Exciter Systems," presented at the 36th Annual Convention of the American Institute of Electrical Engineers, held at White Sulphur Springs, W. Va., June 29–July 2, 1920.

Connecting-Rod Bolts

The Diesel Engine User's Association of England has devoted much time to the discussion of connecting-rod bolts. The subject is of vital importance, since a number of engine failures have been recorded as due to the fracture of the big end bolts. The subject resolves itself into three heads—material, working stresses and design.

In regard to the material, without question a tough substance is highly desirable. Some builders have a preference for wrought iron, claiming that it has less dangerous crystalline tendencies. The majority of manufacturers and users favor some form of steel bolts, either of ordinary carbon steel or of a high-tensile alloy steel. Considerable variation in opinion as to the advisability of heat treating the bolts was expressed. Apparently, the majority felt that, if heat treatment was adopted, the steel should be treated while in the bar rather than after being machined. It was suggested at one of the meetings that bolts in service should be heat-treated at stated intervals. Several members claimed that heat treatment lowered the elastic limit of the steel and did not increase the life of the bolt. Examples were cited on bolts that had been in service for 25,000 hours without heat treatment.

It was brought out that the big end bolts are subjected to tensile stresses every second revolution, due to the inertia of the piston during the exhaust and suction stroke. These stresses are augmented if the piston is a very close fit or if piston seizure occurrs. This must be taken into account when designing the bolt.

The May meeting of the association was devoted to a further discussion of the subject. The statement was offered that the bearing clearance played an important part in the determination of the actual stresses in the bolts, since an impact occurred between the crankpin and the bearing at each reversal of the stress. Furthermore, the torsional vibration of the crankshaft when the engine passed through the critical speed point, in those cases where the critical speed was below the normal speed, had some effect on the bolt stress. One member suggested that something should be allowed in consideration of the initial stress due to tightening the nut, over and above the stresses arriving from the inertia forces. He thought it necessary to provide a comfortable margin in the design to insure safe operating condition. It was also stated that the working temperature might affect the tightness of the nut, greatly increasing the impact stress by loosening the bearing. Attention was called to some notes on "Gas and Oil Engine Accidents," issued by one of the insurance companies, from which it appeared that 25 per cent of the total engine failures resulted from fracture of the connecting-rod bolts. (*Power*, May 25, 1920.)

Mr. Charles Day, in a communication to the association, wrote that the rod bolts usually adopted are quite suitable for the normal stresses arising from the inertia of the piston, etc. In his opinion breakage was due, almost invariably, to abnormal conditions such as excessive piston friction, improper tightening of the nuts, and slack bearings. As to improper tightening, bolts were often injured by being sledged up excessively hard, thus unduly stretching the bolts and at times twisting them. Many bolts are injured by the workmen sledging the nuts in order to bring the cotter hole in the bolt in line with the castellation on the nut. To remedy this, he suggested increasing the number of castellations and placing two holes in the bolt instead of one.

Considering the effect of excessive friction, he continued, this may vary from a slight excess to a severe seizure. In the latter event the bolts will probably be badly stretched or broken. When, however, the stress has not been sufficient to show a decided stretch in the bolt, the question arises as to whether the bolts have been injured. To detect a slight elongation he recommended that a definite length be marked on the bolt when installed; the length should be measured from the bottom of the bolt head to a point on the thread. To facilitate locating the point a flattened surface could be filed on a thread and a small center punch used. A stretch of 2 per cent should be considered as justifying renewal of the bolt.

For some years, Mr. Day stated, his firm had been experimenting with various steels. It has now adopted the following specifications for the material for the rod bolts: Carbon, 0.30 to 0.40; silicon, 0.30 maximum; manganese, 0.50 to 0.80; nickel, 2.75 to 3.25; sulphur and phosphorus, as low as possible. The material to be oil hardened and tempered to give the following values: Tensile strength, not less than 100,000 lb.; field point, 56 per cent; elongation, 20 per cent; reduction of area, 45 per cent; impact value, 40 ft.-lb.

Duquesne Light Company to Install 60,000-Kw. Unit

So great has been the demand for electric energy by various industries of the Pittsburgh district that the Duquesne Light Co. has been compelled to arrange for the doubling of the proposed initial installation of 60,000 kw. at its new Colfax power plant. The second 60,000-kw. turbine-generator with 100,000 sq.ft. surface condensers divided in four shells, which has just been ordered from the Westinghouse Electric and Manufacturing Co., will be a duplicate of the first machine. It will be designed to operate at maximum efficiency when subjected to a load of 50,000 kw. and to take care of a maximum load of 70,000 kw. for short periods.

Steam will be supplied to the turbine at 275-lb. pressure, 175 deg F. superheat and 29-in. vacuum.

In addition to the equipment mentioned, a 2,000-kw. a.-c. house turbine has been ordered to furnish energy for the plant auxiliaries.

The official inquiry into the explosion of a boiler blowdown pipe at Birtley, Durham, indicates an unusual cause of failure. The blowdown pipe parted from the valve, and the resultant discharge of boiling water killed the attendant. On examination of the pipe it was found that the part screwed into the flange was eroded almost entirely away at the upper quarter of its circumference. This was evidently caused by the scouring action of the sediment from the mud drum, which had continued to erode the inside of the pipe until it reached the bottom of the threads. On the same boiler a similar pipe, which is used for blowing from the other end of the same mud drum, was found to be in an almost exactly similar condition. Both pipes had two deep scores about 90 deg. apart on the inner circumference. These scores or grooves were about ¼ in. wide, and extended about 1½ in. into the pipes, tapering away to nothing. The metal between the scores was wasted to a smaller extent. In another valve, by the same makers, it was found that in the outlet passage there were four projections at angles of 90 deg. to one another. The lower ones evidently had the effect of causing the sediment to flow in two streams in an upward direction of about 30 deg. to the horizontal, thus impinging on the edge of the pipe where screwed into the flange.—*The Engineer.*

The latest figures on the world's oil supply given out by the United States Geological Survey show that foreign countries are using only half as much petroleum as the United States, but have seven times as much oil in the ground. These foreign countries have an oil supply sufficient to last for 250 years at the present rate of consumption while in the United States at the present rate of consumption there is only an eighteen-year supply.

Hydro-electric power developments in India are advancing with great strides, according to the July 13 issue of *Commerce Reports*. Construction of power plants has centered particularly in Mysore state. The whole valley of the Cauvery has been surveyed with a view to increasing the existing power output. The gold fields in this state require much more power to carry on operations and produce a maximum amount of gold.

Notes on the Coal Situation

That New York City's yearly coal bill is running at least $10,000,000 in excess of what it ought to be was one of the facts brought out at the hearing of the Senate Committee on Reconstruction and Production, at its offices, 29 West 39th St., New York City. The witnesses were representatives of the public utilities and the Public Service Commission of New York City, and a representative of the public utilities and coal consumers of northern New York State.

The figures relating to the city's coal bill were brought out in the testimony given by John W. Lieb, vice-president of the New York Edison Co. The public utilities of New York, Mr. Lieb said, consume roughly 5,000,000 tons of coal annually. This includes both bituminous and anthracite, but the latter is only an insignificant portion of the total. At a conservative estimate, owing to the necessity of purchasing spot coal where and how it can be obtained, the coal bill of the public utilities is running at a rate of from seven to eight million dollars in excess of its normal amount. Adding two to three million dollars increase in the price of coal to citizens for heating purposes makes the total of more than $10,000,000 increase.

Answering a question by Senator William M. Calder, chairman of the committee, Mr. Lieb said that normally the Edison company had in storage between 150,000 and 200,000 tons of coal. At the beginning of last winter the quantity was less, 120,000 to 125,000 tons, and that reserve was finally exhausted a month or two ago.

Senator Calder was interested particularly in the question of spot coal. Mr. Lieb testified that under contracts already made his company was receiving only 52 per cent of the coal contracted for. For any additional supply it was dependent on spot coal. The ordinary contract price for coal at the mine, Mr. Lieb said, was $4.25 to $4.75, whereas for spot coal his company had been paying up to June 26 from $7.50 to $10.25. Since that date, he said, some coal had been bought as high as $12 at the mine.

Questioned as to the effect of the recent Order No. 10, of the Interstate Commerce Commission, giving preferential assignment of cars to the Northwest, on the situation of public utilities, Mr. Lieb said that he viewed the new order with a good deal of concern. "If this order," he said, "gives priority over the public-utilities order, we shall soon be in difficulties again, and the public utilities of New York City will have to shut down."

Commissioner Alfred M. Barrett, Deputy and Acting Public Service Commissioner for the First District, declared that if an improvement did not soon take place in the situation "something will happen, and New York City will close down. We are not getting coal in summer," he said, "and winter will come and the householders will demand coal. If the railroads cannot carry enough soft coal now, what will they do when part of their cars are carrying hard coal?" Twenty-five thousand tons of coal a day he estimated to be the requirement of New York City for its public utilities, and in the first week of July, he said, these utilities had on hand a total supply of not more than 137,000 tons, or enough to last one week. The situation has improved slightly since then, he said, and last Thursday there was a ten-day supply on hand.

Robert W. Bush, of the Brooklyn Union Gas Co., gave evidence revealing a similar critical situation in his company as that revealed for the Edison company.

Order No. 10 of the Interstate Commerce Commission, granting prior rights in the use of coal cars to the Northwest, was bitterly assailed by John M. Carlisle, of Watertown, N. Y., representing the paper mills, public utilities and coal consumers of northern New York State. Mr. Carlisle's evidence revealed an exceedingly critical situation up state. "If 4,000 carloads a day are to be shipped to the Northwest territories," he said, "it means that a practical embargo is declared against other sections of the country. Twenty-five thousand to thirty thousand tons of bituminous coal must be stored up at Watertown during the summer months for winter use. Climatic conditions in the winter make the shipment of coal impossible. For that reason we have got special tariff provisions permitting the bringing and storage of coal during the summer. Today there is not a ton of coal in storage in Watertown, whereas last year at this time we had 30,000 tons."

The Coal Transportation Problem

That the Interstate Commerce Commission was not impressed by the arguments advanced by those asking the modification of its order giving coal mines prior use of open-top cars was proved conclusively when the commission extended its order for an additional thirty days and issued Service Order No. 10, which will force coal from Pennsylvania, Ohio, West Virginia and Kentucky up the Lakes. The main effort on the part of those opposing the order was intended to impress the commission with the importance of their respective activities. In this they failed, in large measure because the commission took the stand that an adequate supply of fuel took precedence over any such activity as building or road construction.

The really telling point made by the opposition was that thousands of open-top cars are in the service of non-essential industries in the transportation of their coal. The contention is that cars should be available to prevent millions of dollars' worth of highways from being destroyed when the cars needed for this purpose are busy carrying coal reserves to the candy factories. Another example is the plea of the constructional industries, who point to the unrest being engendered by inadequate housing. It looks unfair to them to see trainload after trainload of cars engaged in coal transport to automobile factories, while they are able to secure only 2 per cent of the cars needed in connection with the building of homes.

It is believed that the coal operators and the railroads will be able to work out plans which will insure New England, the Northwest and Canada an adequate coal supply for the winter. The award by the Railroad Labor Board is having the effect of facilitating greatly the movement of cars, and it is believed that the worst of the situation is past. Owing to the prospects of improvement it is believed that the immediate appointment of a fuel administrator has been averted.

A second effort has been made to relieve the coal shortage in New England. Service order No. 11, issued July 27, repeals service order No. 6, issued June 19. The order was drafted by the operators and the representatives of the carriers. It is entirely satisfactory to representatives of New England, and the operators believe that it will relieve the situation entirely. Those most likely to be hurt by the order are consumers other than New England who depend upon the smokeless field for their fuel supply. These consumers, however, have been assured by the railroads that there will be no curtailment of their coal supply, as arrangements have been made to give mines shipping to New England all the cars that they can load. This will mean that there will be enough to meet the New England allotment and allow a remainder sufficient to supply other consumers.

One of the important features of the order is the placing of the three tidewater agencies at Hampton Roads under the direction of a single agent of the Interstate Commerce Commission. Under order No. 6, there were separate agents at Newport News, Lambert's Point and Sewell's Point.

To meet the requirements of the New England States, 1,250,000 tons of bituminous coal must be transported by rail and water each month. At the present rate of transportation New England is short about 350,000 a month.

It was ordered that bituminous coal in carloads consigned under this order should not be subject to reconsignment except upon a permit issued by the agents of the commission. A permit will be issued only on a showing that the coal to be reconsigned will go to a pool or pools at one of the ports for New England.

Shippers having credit at any of the tidewater ports, that have been obtained by the shipment of coal into the pool of coal consigned under this order, will not be per-

mitted to draw against this credit and ship from the pool to any destination excepting those in New England.

Committee To Fix Profit

A committee to fix a fair margin of profit on coal has been appointed by Attorney General A. Mitchell Palmer. The committee is composed of Vance McCormick and William Potter, representing the public; J. W. Lieb, vice president of the New York Edison Co., representing the utility companies; G. N. Snyder, of the New York Central, representing the railroads, and Willis G. Townes, Charles A. Owen, Harlow Voorhees and Charles L. Couch, representing the wholesale coal dealers.

The New York *World* in an editorial says:

"When, as alleged, concerns that had contracted ahead for coal at normal prices of $4 to $4.50 can get no coal, while offered plenty at $11, and coal for export sells up to $23, consumers have the best reason in the world to call on the Government for protection. This is brigandage plain and simple, and the quickest way to suppress it is to restict exports until the home market is restored to a stable basis. If some of the worthy persons engaged in rigging prices should find their way to jail, it would cause no mourning."

COAL PRICES OF THE COUNTRY

Embargoes in New England have resulted in a mild recession in prices. For two or three days sales were made at $10.50 per net ton f.o.b. mines on mediocre grades, but on July 24 sales were again made on the basis of $13.75 at mines. On cars at Boston quotations of $17.50 to $20 are made on low volatiles.

Philadelphia—A moderate volume of soft coal was begining to enter Philadelphia when the Pennsylvania R.R. declared an embargo. Public utilities are unaffected by the embargo. The price for stock remains high with $15 as the top. The bulk of sales are made nearer $13.50 for the better Pennsylvania coal. The utility plants are working under the new plan of filling out forms by which they obtain assignment of a certain number of empty cars to the mines of the companies with whom they have contracts.

Baltimore—The price situation is out of control with sales made right along at from $11 to $13 per net ton f.o.b. mines, almost irrespective of grade. Prices at piers have been as high as $17 and $18 per gross ton. The extraordinary demand, both export and domestic, continues unabated. Of the 70 ships in the harbor for coal a week ago and for several weeks past, 30 of them have already been to other ports.

Bituminous

Buffalo—The price of $10.50 at the mine is considered rather low, but is accepted for the Buffalo bituminous trade. It seems to be the general belief that a decline is due before very long because of the fact that production is now a little in excess of consumption and cars are more plentiful.

Detroit—With the summer more than half gone practically no reserves have been created for industrial plants, public utilities, or retail yards; in fact, consumers in all lines are becoming apprehensive of a bituminous coal shortage in Michigan next winter. Under the direction of the Michigan Public Utilities Commission a conference was held in Lansing on July 21 to discuss the situation and plan relief. It was decided that a state coal commission of five or more members to be named by the governor should be appointed. The miners' strike in Illinois threatens to diminish still further the meager supply of coal.

Cincinnati—There is no shortage of soft coal in Cincinnati, but there is a distinct scarcity of smokeless and anthracite. The scarcity of coal cars does not affect this city because of river transportation. It is possible to obtain coal at $8.50 per ton as against $4 for the same coal in Toledo.

Chicago—The coal strike in southern Illinois has, of course, occasioned considerable worry in Chicago. Manufacturers who thought they were covered now find themselves face to face with shut-down conditions. Mines in Indiana have not been affected as yet and are, of course, swamped with inquiries. Naturally the market is advancing.

Louisville—Production in Kentucky has increased as a result of a better car supply. However, demand is keeping pace with production and prices remain about the same as during the last few weeks as follows: Eastern Kentucky gas mine run $9 to $9.50, non-gas $8.50 to $9, western Kentucky lump $5 to $5.50 average, mine run $4.50 to $4.75, screening $4.50 to $4.75. Some west Kentucky lump is selling as high as $6.75.

New Construction

PROPOSED WORK

Conn., New Haven—Yale University will soon award the contract for a 4 story dormitory including a hot water heating system on the campus. About $400,000. W. A. Delano, 126 East 38th St., New York City, Archt.

Conn., Norwalk—The city plans to construct a 2 story electrical plant. Two 300 kw. rotary convertors with transformers, etc., will be installed in same. About $50,000. Westcott & Mapes, Inc., 207 Orange St., New Haven, Engrs.

Conn., West Hartford—The Bd. Educ. will receive bids until September 1 for a 2 story, 200 x 204 ft. high school including a steam heating system on South Main St. About $500,000. W. T. Marchant, 36 Pearl St., Hartford, Archt.

N. J., Secaucus—The Blvd. Comrs. of Hudson Co. will soon receive bids for the installation of a motor power electric plant in their power house here. About $30,000.

Pa., Bethlehem—The Chamber of Commerce is having plans prepared for a 10 story, 116 x 120 ft. hotel including a steam heating system. About $500,000. Verus T. Ritter, North Amer. Bldg., Archt.

Pa., Derry—The Pittsburgh High Voltage Insulator Co. has purchased a site adjoining its present property and plans to construct a power house, machine shop, etc., on same.

Pa., Elmhurst—The Greek Catholic Society of America is having plans prepared for a 3 story, 110 x 200 ft. orphanage including a vapor heating system. About $350,000. Morris & MacHale, Burr Bldg., Scranton, Archts.

Pa., McKeesport—The Bd. Educ. will receive bids until August 9 for the installation of a 2 story school. Separate bids for installing a heating system will be received. About $325,000.

Pa., Port Blanchard (Pittston P. O.)—The Pennsylvania Coal Co., River Rd., is having plans prepared for a 100 x 400 ft. coal breaker including a steam heating system and electric power on the Main Rd. About $1,000,000.

Pa., Scranton—Fred Nelson, Archt., Cornell Bldg., is preparing plans for a 3 story, 50 x 100 ft. factory including a steam heating system, electric motors, etc. About $100,000. Owner's name withheld.

Pa., Sunbury—The Sunbury Trust & Safe Deposit, c/o Verus T. Ritter, Archt., Amer. Bldg., Philadelphia, is having plans prepared for a 6 story, 60 x 120 ft. bank and office building including a steam heating system. About $500,000.

Pa., Wilkes-Barre—The School Bd. is in the market for two steam boilers about 20 hp. each.

Ky., Blackey—The Kentucky & West Virginia Power Co. of Whitesburg plans to extend its transmission lines from here into the Elkhorn coal fields to Pikeville, where a large substation will be built.

O., Cleveland—Jacob Babin, 827 Superior Ave., has purchased a site at 3602 Euclid Ave. and plans to build a 4 story, 50 x 200 ft. mercantile building including a steam heating system. About $250,000.

O., Cleveland—The Water Ice Co., c/o A. C. Bishop & Co., Archts. and Engrs., 427 Guardian Bldg., will soon award the contract for a 1 story, 45 x 142 ft. ice plant on West 25th St. About $100,000. Noted July 27.

O., Eaton—The city plans to build a new filtration plant for the local waterworks including pumps, sand filters, etc., at $27,500.

O., Lakewood (Cleveland P. O.)—The city has retained E. A. Fischer, Engr., City Hall, to make a survey and submit estimates for the construction of a pumping station and water system.

O., Warren—The Warren Hotel Co., c/o F. E. Robbinson, Guardian Bldg., Cleveland, is having plans prepared for the construction of an 8 story, 80 x 180 ft. hotel including a steam heating system. About $1,000,000. Moulthrop & Nichols, 5716 Euclid Ave., Cleveland, Archts.

Ind., Crown Point—The Bd. of County Comrs. had plans prepared for a 2 story, 100 x 200 ft. hospital including two boilers, etc., here. About $400,000. J. N. Coleman, 6257 St. Lawrence St., Chicago, Archt.

Ind., Indianapolis—The Indianapolis Athletic Club plans to build an 11 story club building including a steam heating system on Meridian and St. Clair Sts. About $2,000,000. Henry F. Campbell, Pres.

Ind., Richmond—The Bd. of Pub. Wks. will receive bids for a 500 kw. turbine and other equipment for the lighting plant here.

Mich., Detroit—The Bd. of Fire Comrs., West Larned St., will soon award the contract for a 2 story, 50 x 80 ft. fire engine house including a seam heating boiler, etc., on Davison Ave. and Goddard St. About $100,000. Charles Knotting, 2306 Dime Bank Bldg., Archt.

Mich., Detroit—The Bd. Educ., 50 B'way, will receive bids until August 11 for a 2 story, 46 x 117 ft. school on Coplin Ave., $200,000; 2 story, 164 x 206 ft. addition to

the Jane Cooper School on the South Side of Georgia Ave. between Helen and Concord Aves., $330,000; 2 story, 50 x 125 ft. addition to the Nellie Leland School on the corner of Russell and Catharine Sts., $200,000; 2 story, 58 x 211 ft. addition to the Custer School Building on Linwood Blvd. and Midland Ave., $300,000, and a 2 story, 44 x 120 ft. addition to the Crossman School on Hamilton Blvd. and Taylor Ave., $170,000. A plenum steam heating system will be installed in each.

Mich., Detroit — The Bd. Educ. received bids for the installation of a heating, ventilating and plumbing system in the proposed 2 story, 105 x 200 ft. Pattengill School on Northfield and Spokane Aves., from Irvine & Meier, 2289 Woodward Ave., $94,272; in the proposed 2 story, 77 x 159 ft. George School on Russell and Superior Sts., the proposed 2 story White School on Charles Ave., and the proposed 2 story Davison School on Roman and Joseph Campau Aves., from James W. Partlan, 51 Park Pl., $56,995; $92,850; O'Conor Bros., Vinton Bldg., $60,446; $99,998; $85,741. Noted July 20.

Mich., Detroit — The Michigan Creamery Co., c/o Samuel Raboniwitch, Ford Bldg., is having preliminary plans prepared for a 7 story creamery plant along the Grand River here. Plans include a steam power plant, refrigeration system and power operated equipment. T. A. Hyland, 307 Moffat Bldg., Archt.

Mich., Kalamazoo—The Bd. Educ. is having plans prepared for a 2 story, 159 x 362 ft. school including a steam heating system on North Burdick St. R. A. LeRoy, 122 Pratt Block, Archt.

Mich., Traverse City—The City Lighting Dept. plans to build a steam electric power plant. About $75,000.

Ill., Chicago—The Rogers Park Hotel & Bldg. Corp., c/o B. Leo Steif & Co., Archt., 30 North La Salle St., is having plans prepared for a 9 story, 140 x 150 ft. apartment hotel on Sheridan Rd. and Pratt Blvd. Plans include a refrigeration plant, steam heating system, etc. About $1,300,000.

Ill., Chicago—The Standard Electric Mfg. Co., 216 North Clinton St., has purchased a site on Wrightwood Ave. and plans to build a 2 story, 125 x 150 ft. factory including a steam heating system on same. About $250,000.

Ill., Monticello—J. C. Llewellyn, Archt., 38 South Dearborn St., will soon award the contract for a 2 story, 112 x 172 ft. school including a steam heating system and ventilation plant for the city. About $225,000.

Wis., Milwaukee — The Park Bd., City Hall, will soon award the contract for furnishing new boilers in the Mitchell Park Conservatory. About $4,500.

Minn., Minneapolis — The State Bd. of Control, Capitol, St. Paul, received bids for installing a heating system in the proposed 3 story addition to the Chemistry Building on the State University campus here from the Hamline Plumbing & Heating Co., 683 Snelling Ave., North, St. Paul, $87,849; Archambo Heating & Plumbing Co., 315 5th Ave., South, $88,919; Belden Porter Gray & Co., 914 Mary Place, $88,996.

Minn., Red Wing—The Lutheran Ladies' Seminary plans to build a 3 story, 120 x 250 ft. seminary including a steam heating system. About $400,000. A. C. Gauger, 302 Central Bank Bldg., St. Paul, Minn., Archt.

N. D., Grand Forks — The Industrial Comm. of North Dakota will soon award the contract for the installation of 17 motors of varius sizes in the new terminal mill and elevator here. C. L. Pillsbury Co., 805 Metropolitan Life Bldg., Minneapolis, Minn., Engr.

Okla., Erick—The city plans to build a sewer system and enlarge the light and power plant. About $120,000. J. A. Richardson, Mgr.

N. M., Fort Stanton — J. A. Wetmore, Supervising Archt., Treasury Dept., Wash., D. C., will receive bids until August 16 for remodeling boiler here.

Idaho, Worley—The Bd. of Trustees of the village will receive bids until August 7 for an electric power line from here to Plummer, a distance of 7 miles. J. P. Mathews, Village Clk.

Wash., Prossor—The Nyberg & Gallwin Fruit Co. will soon award the contract for a cold storage plant. About $75,000.

Ore., Portland — Joseph R. Keep, 313 Couch Bldg., has filed an application with Percy A. Cupper, State Engr., for permission to divert 4,000 second feet of water from the Sandy River and its tributaries. The project will probably include a power plant in Clackamas County.

Que., Montreal—The United Hotel Co. had preliminary plans prepared for a 10 story hotel including heating, power, ventilating and refrigeration systems. About $8,000,000. Ross & Macdonald, Belmont St., Archts.

Ont., Kingston—Queens University plans to construct a 3 story students' union building including a steam heating system on the university grounds here. About $350,000.

Ont., Kitchener — The Hospital Bd. will receive bids until August 7 for a new power house and steam heating plant for the General Hospital. About $15,000. A. R. Kaufman, Chn.

Ont., London—The city plans to construct a city hall including a steam heating system, etc. About $1,250,000.

Ont., London—W. G. Murray, Dominion Savings Bldg., is in the market for an electric motor and waterworks pumping equipment to supply new school.

CONTRACTS AWARDED

Mass., Boston — The Commonwealth of Massachusetts has awarded the contract for the installation of a ventilating system in various rooms at the State House Building here to the Cleghorn Co., 54 Batterymarch St., at $55,310.

Mass., Boston — The Schoolhouse Comm. has awarded contract for the installation of a steam heating system in the Louisa M. Alcott School to J. J. Hurley, 104 B'way, at $13,394. Noted July 13.

Mass., Boston — The Washington Essex Bldg. Trustees, c/o 723 Scollar Bldg., has awarded the contract for a 4 story theatre, etc., including a steam heating system on Washington and Essex Sts., to the George B. H. Macomber Co., 44 Bromfield St., at $1,500,000. Noted July 30.

Mass., Framingham—The Record Realty Co. has awarded the contract for a 1 story, 50 x 50 ft. power house to the E. A. Abbott Co., 3 Park St., Boston, at $35,000.

N. Y., Wards Island—L. F. Pilcher, State Archt., Albany, has awarded the contract for the installation of electric generators at the Manhattan State Hospital here to T. Frederick Jackson, Inc., 99 John St., New York City, at $14,350.

N. J., Butler—The town has awarded the contract for the construction of a power house addition to Harold Bang, 188 19th Ave., Paterson, at $15,675; for the installation of a steam heating system to John R. Proctor, 19 West 19th St., Bayonne, and for power equipment to John R. Hooly, 95 Liberty St., New York City, at $40,457.

N. J., Newark—The Osborn Branch of the Amer. Color Type, 759 Summer Ave., has awarded the contract for a 1 story, 43 x 75 ft. power house to Samuel Marshall, Arlington, at $50,000.

Pa., Erie — The Second Natl. Bank, 8th and State Sts., has awarded the contract for a 1 story, 60 x 130 ft. bank building including a steam heating system on 9th St. to Henry Shenk, Erie, at $400,000. Noted July 7.

Pa., Philadelphia—The Academy of the Sacred Heart, Convent Lane and Bristol Pike, has awarded the contract for a 1 story boiler house addition to Thomas Reilly, 1616 Thompson St., at $15,000.

Md., Baltimore—The Bd. of Awards, City Hall, has awarded the contract for installing heating furnaces in Schools 23, 34, 42, 68 and 80 to Charles Schulz, 1435 Central Ave.; steam heating plant in School 12 to James McCrea & Son, 19 North Carrollton Ave., and in Schools 3, 20, 54 and 99 to Riggs, Distler & Stringer, 216 North Calvert St.

Va., Petersburg—The Ambursen Constr. Co., 186 5th Ave., New York City, will build a dam on Swift Creek. Plans include a power house. Work will be done by day labor.

O., Cleveland — The Bd. Educ., has awarded the contract for a 1 story, 30 x 66 ft. heating plant at East 92nd St. and Parkgate Ave. to the Drummond Miller Co., 4500 Euclid Ave., at $100,000.

O., Cleveland—The city has awarded the contract for furnishing and installing two 8,000,000 gal. and one 4,000,000 gal. motor driven vertical centrifugal pumps with motors, electrical equipment, etc., to the Dravo-Doyle Co., Diamond Bank Bldg., Pittsburgh, Pa., at $20,736. Noted March 16.

Mich., Detroit — The Chinese Merchants' Association, 187 3rd St., has awarded the contract for a 5 story, 78 x 185 ft. hotel including a steam heating system on Woodward Ave. to Shank & Co., 38 South Dearborn St., Chicago. About $800,000.

Mich., Ironwood—Alvord & Burdick, 1417-18 Hartford Bldg., Chicago, has awarded the contract for a pumping station, substations and engineer's residences to W. S. Peters, Wakefield, at $62,613, and for centrifugal pump equipment to the Lee Courtenay Co. at $27,600.

Ill., Chicago — The Canton Bldg. Corp., c/o Fugard, Knapp & Walter E. Perry, Archts., 64 East Van Buren St., has awarded the general contract for a 3 story, 80 x 111 ft. restaurant including a steam heating system and refrigeration plant on Wabash and Van Buren Sts. to Henry Ericson Co., 139 North Clark St. About $200,000.

Ia., Cushing—A. H. Bullock, Secy. of the Bd. Educ., has awarded the contract for the installation of a heating and plumbing system in the proposed 3 story, 59 x 111 ft. school to O. J. Saquety, Holstein, at $19,100. Noted Dec. 23.

Ia., Larabee—H. Montgomery, Secy. of the Bd. Educ., has awarded the contract for the installation of a heating and plumbing system in the proposed 3 story, 82 x 139 ft. school to the Mathew Plumbing Co., LeMars, at $23,000.

Ia., Morning Sun—O. F. Boller, Secy. of the Bd. Educ., has awarded the contract for the installation of a heating and plumbing system in the proposed 2 story, 56 x 120 ft. school to Carstens Bros., Ackley, at $27,174. Noted March 23.

Ia., Packwood—N. E. Olliver, Secy of the Bd. Educ., has awarded the contract for the installation of a plumbing and heating system in the proposed 2 story, 58 x 99 ft. school to the W. D. Reed Plumbing and Heating Co., 3405 Independent Ave., Kansas City, Mo., at $18,675. Noted March 23.

Ia., Pocahontas—W. J. Gilchrist, Pres. of the School Bd., has awarded the contract for the installation of a heating and plumbing system in the proposed 2 story, 56 x 110 ft. school, to Thomas Reinhart, LeMars, at $25,000.

Minn., Deer River—The Bd. Educ. has awarded the contract for the installation of a heating and ventilating system in the proposed 2 story school here to D. R. Black & Co., 314 West 1st St., Duluth, at $26,186. Noted March 30.

Kan., Bushong—The Missouri Pacific Ry. Co., Ry. Exch. Bldg., St. Louis, Mo., has awarded the contract for a new water service system including a pump house, steel tank, distributing system, engine and pump here to Joseph E. Nelson & Sons, 3240 South Michigan Blvd., Chicago, Ill.

Mo., St. Louis — The city has awarded contract for one 220 brake hp. horizontal, single, direct-connected side crank engine for the sanitarium pumping station to the Chuse Engine & Mfg. Co., 721 Olive St., at $8,917.

Mo., St. Louis—The General Natl. Bank, B'way and Olive St., has awarded the contract for altering building on 7th and Olive Sts., to R. S. Price, Arcade Bldg., at $100,000. A 15-ton refrigerating plant will be installed in same.

Ont., Hamilton — The Firestone Tire & Rubber Co., Sherman Ave., has awarded the general contract for a 4 story tire and rubber factory on Sherman Ave. to the Piggott Healey Constr. Co., 36 James St., South, at $500,000. Contract for installing heating, etc., in same will be sublet.

SEE SEARCHLIGHT SECTION
Pages 116-128

PRICES - MATERIALS - SUPPLIES

Electrical prices on following page are prices to the power plant by jobbers in the larger buying centers east of the Mississippi. Elsewhere the prices will be modified by increased freight charges and by local conditions.

POWER-PLANT SUPPLIES

HOSE—

	Fire
Underwriters' 2½-in.	85c. per ft.
Common, 2½-in.	30%

	Air		
	First Grade	Second Grade	Third Grade
¾-in. per ft.	$0.60	$0.40	$0.30

Steam—Discounts from List

First grade..... 20% Second grade.....30% Third grade....45%

RUBBER BELTING—The following discounts from list apply to transmission rubber and duck belting:

Competition..... 50% Best grade..... 20%
Standard..... 30–10%

LEATHER BELTING—Present discounts from list in fair quantities (½ doz. rolls):

Light Grade	Medium Grade	Heavy Grade
30%	25%	20%

RAWHIDE LACING { For cut, best grade, 25%, 2nd grade, 30%
For laces in sides, best, 79c per sq. ft.; 2nd, 75c.
Semi-tanned: cut, 20%; sides, 83c per sq. ft.

PACKING—Prices per pound:

Rubber and duck for low-pressure steam	$1.00
Asbestos for high-pressure steam	1.70
Duck and rubber for piston packing	1.00
Flax, regular	1.20
Flax, waterproofed	1.70
Compressed asbestos sheet	.90
Wire insertion asbestos sheet	1.50
Rubber sheet	.50
Rubber sheet, wire insertion	.70
Rubber sheet, duck insertion	.50
Rubber sheet, cloth insertion	.30
Asbestos packing, twisted or braided and graphited, for valve stems and stuffing boxes	1.30
Asbestos wick, ½- and 1-lb. balls	.85

PIPE AND BOILER COVERING—Below are part of standard lists, with discounts.

PIPE COVERING		BLOCKS AND SHEETS	
Pipe Size	Standard List Per Lin.Ft.	Thickness	Price per Sq.Ft.
1-in.	$0.27	½-in.	$0.27
2-in.	.36	1 -in.	.30
6-in.	.80	1½-in.	.45
4-in.	.60	2 -in.	.60
3-in.	.45	2½-in.	.75
8-in.	1.10	3 -in.	.90
10-in.	1.30	3½-in.	1.05

85% magnesia high pressure ..... List

For low-pressure heating and return lines { 4-ply ..... 50% off
3-ply ..... 52% off
2-ply ..... 54% off

GREASES—Prices are as follows in the following cities in cents per pound for barrel lots:

	Cincinnati	Chicago	St. Louis	Birmingham	Denver
Cup	8½	6.6	8½@9½	8½	13¼
Fiber or sponge	8½	8.6	8½@9½	8½	20
Transmission	10	8.1	12@14	8½	20
Axle	...	4.8	5½@6½	5½	7¼
Gear	6½	6.1	6½@6¾	5½	8½
Car journal	12(gal.)	4.7	8½@9½	8½	8½

COTTON WASTE—The following prices are in cents per pound:

	New York			
	Current	One Year Ago	Cleveland	Chicago
White	15.00@17.00	13.00	16.00	11.00 to 14.00
Colored mixed	9.00@14.00	9.00 to 12.00	12.00	9.50 to 12.00

WIPING CLOTHS—Jobbers' price per 1000 is as follows:

	13½ x 13½	13½ x 20½
Cleveland	$55.00	$65.00
Chicago	41.00	43.50

LINSEED OIL—These prices are per gallon:

	New York		Chicago	
	Current	One Year Ago	Current	One Year Ago
Raw in barrels (5 bbl. lots)	$1.53	$1.90	$2.02	$2.10
5-gal. cans	1.56	2.03	2.27	2.30

*To this *oil* price must be added the cost of the cans (returnable), which is $2.25 for a case of six.

WHITE AND RED LEAD—Base price per pound:

	Red				White	
	Current		1 Year Ago		Current	1 Yr. Ago
	Dry	In Oil	Dry	In Oil	Dry and In Oil	Dry and In Oil
100-lb. keg	15.50	17.00	13.00	14.50	15.50	13.00
25- and 50-lb. kegs	15.75	17.25	13.25	14.75	15.75	13.25
12½-lb. keg	16.00	17.50	13.50	15.00	16.00	13.50
1-lb. cans	18.50	20.00	15.00	16.50	15.00	15.00
5-lb. cans	20.50	22.00	16.00	17.50	16.00	16.00

500 lb. lots less 10% discount; 2000 lb. lots less 10–2½%.

RIVETS—The following quotations are allowed for fair-sized orders from warehouse:

	New York	Cleveland	Chicago
Steel ½ and smaller	List net	30%	30%
Tinned	List net	30%	30%

Boiler rivets, ¾, ⅞, 1 in. diameter by 2 in. to 5 in. sell as follows per 100 lb.:

New York.....$6.00 Chicago.....$5.62 Pittsburgh.....$4.50

Structual rivets, same sizes:

New York.....$7.10 Chicago.....$5.72 Pittsburgh.....$4.60

REFRACTORIES—Following prices are f. o. b. works,

Bauxite brick, 56% alumina, f.o.b. Pittsburgh	M.	$145
Chrome brick, f.o.b. Chester, Pa., carlots	net ton	90–100
Chrome brick, 9 in. strs. and sizes, f.o.b. Baltimore	net ton	90–95
Fire clay brick, 1st quality, 9 in. shapes, f.o.b. Pennsylvania, Ohio and Kentucky works	M.	45–53
Fire clay brick, 1st quality, f.o.b. St. Louis	M.	45–
Fire clay brick, 1st quality, f.o.b. New Jersey	M.	75–
Fire clay brick, 2d quality, 9 in. shapes, f.o.b. Pennsylvania, Ohio and Kentucky works	M.	40–
Magnesite brick, 9 in. straights, f.o.b. Baltimore	net ton	100
Magnesite brick, 9 in. sizes and shapes larger than 9 in.		Regular extras
Magnesite brick, f.o.b. Chester	net ton	90–100
Silica brick, 9 in. and 9 in. sizes, f.o.b. works, Chicago district	M.	55–
Silica brick, f.o.b. Birmingham	M.	51–55
Silica brick, f.o.b. Mt. Union, Pa.	M.	50–55

BABBITT METAL—Warehouse prices in cents per pound:

	New York		Cleveland		Chicago	
	Current	One Year Ago	Current	One Year Ago	Current	One Year Ago
Best grade	90.00	87.00	74.50	79.00	60.00	75.00
Commercial	50.00	42.00	21.50	17.50	15.00	15.00

SWEDISH (NORWAY) IRON—The average price per 100 lb., in ton lots, is:

	Current	One Year Ago
New York	$20.00	25.50–30.06
Cleveland	20.00	20.00
Chicago	21.00	16.50

In coils an advance of 50c. usually is charged.
Domestic iron (Swedish analysis) is selling at 12c. per lb.

SHEETS—Quotations are in cents per pound in various cities from warehouse; also the base quotations from mill:

	Large Mill Lots	New York			
Blue Annealed	Pittsburgh	Current	One Year Ago	Cleveland	Chicago
No. 10	3.55–7.00	7.12@8.00	4.57	8.10	7.02
No. 12	3.60–7.05	7.17@8.05	4.57	8.15	7.07
No. 14	3.65–7.10	7.22@8.10	4.67	8.20	7.12
No. 16	3.75–6.20	7.32@8.20	4.77	8.30	7.22
Black					
Nos. 18 and 20	4.20–6.20	7.80@9.50	5.30	8.70	7.80
Nos. 22 and 24	4.25–6.25	7.85@9.55	5.35	8.75	7.85
No. 26	4.30–6.30	7.90@9.60	5.40	8.80	7.90
No. 28	4.35–6.35	8.00@9.70	5.50	8.90	8.00
Galvanized					
No. 10	4.70–8.00	8.55@11.00	6.20	9.00	8.15
No. 12	4.80–8.10	8.65@11.00	6.25	9.10	8.20
No. 14	4.80–8.10	8.65@11.10	6.30	9.10	8.35
Nos. 18 and 20	5.10–8.40	8.90@11.40	6.60	9.40	8.65
Nos. 22 and 24	5.25–8.55	9.05@11.55	6.75	9.55	9.05
No. 26	5.40–8.70	9.20@11.70	6.90	9.70	9.20
No. 28	5.70–9.00	9.50@12.00	7.20	10.00	9.50

STEEL AND IRON—The following discounts are to jobbers for carload lots on the Pittsburgh basing card, discounts on steel pipe, applying as from January 16, 1920, and on iron pipe from January 7, 1920:

BUTT WELD

Inches	Black	Galv.	Inches	Black	Galv.
⅛ to 3	57 @54	44@41½	⅛ to 1½	34½@24½	18½@ 8
			2 and 2½	33½	17½

LAP WELD

2	50½@47	38@34½	2	28½@20½	14½@ 6½
2½ to 6	53½@50	41@37½	2½ to 6	30½@22½	17½@ 9½
7 to 12	50½@47	37@33½	7 to 12	27½@19½	14½@ 6½
13 and 14	41 @37½	.....			
15	38 @35	.....			

BUTT-WELD, EXTRA STRONG, PLAIN ENDS

⅛ to 1½	55½@52	39½	⅛ to 1½	34½@24½	19½@ 9½
2 to 3	56½@53	44@40½	2 and 2½	34½@24½	19½@ 9½

LAP WELD, EXTRA STRONG, PLAIN ENDS

2	48½@45	37@33½	2	29½@21½	16½@ 8½
2½ to 4	51½@48	40@36½	2½ to 4	31½@23½	19½@11½
4½ to 6	50½@47	39@35½	4½ to 6	30½@22½	18½@10½
7 to 8	46½@43	33@29½	7 to 8	22½@14½	10½@ 2½
9 to 12	41½@38	28@24½	9 to 12	17½@ 9½	5½@ 5½

BOILER TUBES—The following are the prices for carload lots, f. o. b. Pittsburgh:

Lap Welded Steel		Charcoal Iron	
3½ to 4½ in.	40½	3½ to 4½ in.	15½
2½ to 3¼ in.	30½	3 to 3¼ in.	1
2¼ in.	24	2¼ to 2¾ in.	+ 1
1¼ to 2 in.	19½	2 to 2¼ in.	+16
		1¼ to 1¾ in.	+29

Standard Commercial Seamless—Cold Drawn or Hot Rolled

Per Net Ton		Per Net Ton	
1 in.	$327	1¼ in.	$207
1½ in.	267	2 to 2½ in.	177
1¾ in.	257	2¾ to 3½ in.	167
1¾ in.	207	4 in.	187
		4½ to 5 in.	207

These prices do not apply to special specifications for locomotive tubes nor to special specifications for tubes for the Navy Department, which will be subject to special negotiations.

ELECTRICAL SUPPLIES

ARMORED CABLE—

B. & S. Size	Two Cond. M Ft.	Three Cond. M Ft.	Two Cond. Lead M Ft.	Three Cond. Lead M Ft.
No. 14 solid	$104.00(net)	$138.00	$164.00	$210.00
No. 12 solid	135.00	170.00	225.00	265.00
No. 10 solid	185.00	235.00	275.00	325.00
No. 8 stranded	285.00	375.00	520.00	500.00
No. 6 stranded	400.00	500.00	560.00	.....

From the above lists discounts are:

Less than coil lots	+ 5%		+15%
Coils to 1,000 ft.	− 5%	List	Net
1,000 ft. and over	−10%		7%

BATTERIES, DRY—Regular No. 6 size red seal, Columbia, or Ever-Ready:

	Each, Net
Less than 12	$0.45
12 to 50	.38
50 to 125 (bbl.)	.35
125 (bbl.) or over	.32

CONDUIT, ELBOWS AND COUPLINGS—These prices are in 100-lb. lots, f. o. b. New York, with 10-day discount of 5 per cent.

	Conduit		Elbows		Couplings	
Size, In.	Black 2,500 to 5,000 Lbs.	Galvanized 2,500 to 5,000 Lbs.	Black 2,500 to 5,000 Lbs.	Galvanized 2,500 to 5,000 Lbs.	Black 2,500 to 5,000 Lbs.	Galvanized 2,500 to 5,000 Lbs.
⅛	85.00	93.50	22.00	524.60	6.65	7.30
¼	11.50	126.50	29.00	32.00	11.25	12.37
⅜	170.00	187.00	41.00	45.00	15.50	17.00
½	230.00	253.00	52.00	57.00	20.70	23.60
¾	275.00	302.50	70.05	78.00	25.00	27.50
1	375.00	403.00	130.00	145.09	33.70	37.00
1¼	585.00	613.80	210.00	235.00	47.50	53.00
1½	765.00	841.50	560.00	620.00	70.00	78.00
2	920.00	1,012.00	1,350.00	1,485.00	92.00	114.00
2½	1,170.00	1,287.00	1,469.00	1,617.00	115.00	140.00

Standard lengths rigid, 10 ft. Standard lengths flexible, ½ in., 100 ft. Standard lengths flexible, ¾ to 2 in., 50 ft.

CONDUIT NON-METALLIC, LOOM—

Size I. D., In.	Feet per Coil	List, Ft.	
⅜	250	$0.05½	Coils.....40% off
½	250	.06	Less coils, 25% off
⅝	250	.09	
¾	200	.12	
⅞	200	.15	
1	150	.18	
1	100	.25	
1¼	100	.33	
1½	Odd lengths	.40	
2	Odd lengths	.55	

CUT-OUTS—Following are net prices each in standard-package quantities:

CUT-OUTS, PLUG

S. P. M. L.	$0.12	D. P. D. B.	$0.43
D. P. M. L.	.21	T. P. to D. P. S. B.	.26
T. P. M. L.	.33	T. P. S. B.	.38
D. P. S. B.	.23	T. P. D. B.	.64

CUT-OUTS, N. E. C. FUSE

	0-30 Amp.	31-60 Amp.	60-100 Amp.
D. P. M. L.	$0.50	$1.30	$1.68
T. P. M. L.	.70	1.70	2.40
D. P. S. B.	.63	1.60	.....
T. P. S. B.	1.15	2.40	.....
D. P. D. B.	1.10	3.00	.....
T. P. D. B.	1.90	5.40	.....
T. P. to D. P. D. B.	1.30	3.80	.....

FLEXIBLE CORD—Price per 1,000 ft. in coils of 250 ft.:

No. 18 cotton twisted	$23.00
No. 16 cotton twisted	27.50
No. 18 cotton parallel	26.50
No. 16 cotton parallel	34.50
No. 18 cotton reinforced heavy	38.00
No. 16 cotton reinforced heavy	45.00
No. 18 cotton reinforced light	33.50
No. 16 cotton reinforced light	39.50
No. 18 cotton Canvasite cord	30.00
No. 16 cotton Canvasite cord	33.50

FUSES, ENCLOSED—

250-Volt	Std. Pkg.	List
3-amp. to 30-amp.	100	$0.25
35-amp. to 60-amp.	100	.35
65-amp. to 100-amp.	50	.90
110-amp. to 200-amp.	25	2.00
225-amp. to 400-amp.	25	3.60
425-amp. to 600-amp.	10	5.50

600-Volt	Std. Pkg.	List
3-amp. to 30-amp.	100	$0.40
35-amp. to 60-amp.	100	.60
65-amp. to 100-amp.	50	1.50
110-amp. to 200-amp.	25	2.50
225-amp. to 400-amp.	25	5.50
450-amp. to 600-amp.	10	8.00

Discount: Less 1-5th standard package 15%
1-5th to standard package 28%
Standard package 45%

FUSE PLUGS, MICA CAP—

0-30 ampere, standard package	$5.25C
0-30 ampere, less than standard package	6.00C

LAMPS—Below are present quotations in less than standard package quantities:

Straight-Side Bulbs — Mazda B—				Pear-Shaped Bulbs — Mazda C—			
Watts	Plain	Frosted	No. in Package	Watts	Clear	Frosted	No. in Package
10	$0.40	$0.45	100	75	$0.75	$0.80	50
15	.40	.45	100	100	1.10	1.25	24
25	.40	.45	100	150	1.55	1.70	24
40	.40	.45	100	200	2.10	2.30	24
50	.40	.45	100	300	3.15	3.40	24
60	.45	.50	100				12
				500	4.60	4.90	12
				750	6.50	6.90	8
				1,000	7.50	7.95	8

Standard quantities are subject to discount of 10% from list. Annual contracts ranging from $150 to $300,000 net allow a discount of 17 to 40% from list.

PLUGS, ATTACHMENT—

	Each
Porcelain separable attachment plug	$0.24
Composition 2-piece attachment plug	.32
Swivel attachment plug	.20
Current taps	.40

RUBBER-COVERED COPPER WIRE—Per 1000 ft. in New York.

No.	Solid Single Braid	Solid Double Braid	Stranded, Double Braid	Duplex
14	$12.50	$15.50	$17.00	$28.50
12	14.96	18.50	21.45	35.00
10	20.62	24.75	28.05	46.00
8	28.90	33.30	38.50	66.00
6	.....	.....	58.75	.....
4	.....	.....	80.75	.....
2	.....	.....	111.00	.....
1	.....	.....	154.00	.....
0	.....	.....	181.50	.....
00	.....	.....	220.00	.....
000	.....	.....	265.00	.....
0000	.....	.....	330.00	.....

Prices per 1000 ft. for Rubber-Covered Wire in Following Cities:

	Denver			Birmingham			St. Louis		
	Single Braid	Double Braid	Duplex	Single Braid	Double Braid	Duplex	Single Braid	Double Braid	Duplex
14	$15.64	.....	$38.45	$12.23	.....	$38.64	$14.00	$19.75	$38.00
10	24.50	.....	.....	27.60	.....	65.57	23.25	26.25	59.50
8	33.48	$56.81	.....	38.64	.....	87.33	32.60	36.00	80.20
6	.....	77.17	.....	69.12	.....	.....	55.85	57.75	.....
4	.....	108.10	.....	.....	$107.42	.....	80.45	82.75	.....
2	.....	142.00	.....	.....	138.46	.....	120.90	123.65	.....
1	.....	167.70	.....	.....	178.52	.....	156.95	160.45	.....
0	.....	198.20	.....	.....	217.09	.....	195.50	195.50	.....
00	.....	234.60	.....	.....	263.57	.....	.....	.....	.....
000	.....	279.60	.....	.....	320.44	.....	.....	.....	.....
0000	.....	.....	.....	.....	389.17	.....	.....	.....	.....

Pittsburg—23c. base; discount 50%. St. Louis—30c. base.

SOCKETS, BRASS SHELL—

½ In. or Pendant Cap			⅜ In. Cap		
Key Each	Keyless Each	Pull Each	Key Each	Keyless Each	Pull Each
$0.33	$0.30	$0.60	$0.39	$0.36	$0.66

Less 1-5th standard package +50%
1-5th to standard package +20%
Standard package −10%

WIRE, ANNUNCIATOR AND DAMPPROOF OFFICE—

No. 18 B. & S. regular spools (approx. 8 lb.)	55c. lb
No. 18 B. & S. regular 1-lb. coils	56c. lb

WIRING SUPPLIES—

Friction tape, ¾ in., less 100 lb. 60c. lb., 100 lb. lots	55c. lb
Rubber tape, ¾ in., less 100 lb. 65c. lb., 100 lb. lots	60c. lb
Wire solder, less 100 lb. 47c. lb., 100 lb. lots	42c. lb
Soldering paste, 2 oz. cans	$1.20 doz

SWITCHES, KNIFE—

TYPE "C" NOT FUSIBLE

Size, Amp.	Single Pole, Each	Double Pole, Each	Three Pole, Each	Four Pole Each
30	$0.42	$0.68	$1.02	$1.36
60	.74	1.22	1.84	2.44
100	1.50	2.50	3.76	5.00
200	2.70	4.50	6.76	9.00

TYPE "C" FUSIBLE, TOP OR BOTTOM

30	.70	1.06	1.60	2.17
60	1.18	1.80	2.70	3.60
100	2.38	3.66	5.50	7.36
200	4.40	6.76	10.14	13.50

Discounts:

Less than $10.00 list value	+25%
$10 to $25 list value	+10%
$25 to $50 list value	+5%
$50 to $200 list value	−10%
$200 list value or over	−15%